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RATE OF GENETIC IMPROVEMENT IN SWINE AS INFLUENCED BY THE SIZE AND SEX COMPOSITION OF TEST LITTERS[1]

H. T. FREDEEN

Animal Husbandman, Experimental Station, Lacombe, Alberta

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ABSTRACT

A hypothetical breeding unit comprising 20 females and 2 males has been considered. Litters of eight pigs, including equal numbers of each sex, have been studied in order to compute the optimal size and sex combination of individual slaughter test groups from the standpoint of breed improvement.

Examples of the maximum progress possible from selection based on own performance, on sib performance, or on both, when varying numbers and combinations of each sex are slaughtered, are given for several different values of heritability. It is shown that maximal genetic progress is likely to be realized when the test group comprises males only and a minimum of two and a maximum of three pigs are slaughtered.

INTRODUCTION

Swine breeding programs which emphasize improvement of carcass quality must utilize some form of slaughter test to provide the carcass information requisite to selection. Most of the slaughter tests now in use have been patterned after the Danish system of progeny testing and require the feeding, under standardized conditions of management and nutrition, of four pigs from each litter (9). The optimum sex composition of the test litter* is usually considered to be two males and two females. Feed consumption and gain are recorded and the test pigs are slaughtered at a standard weight to provide the desired carcass measurements.

A disadvantage of the test is that the greater the number of pigs slaughtered, the smaller the number remaining for selection. This materially affects the selection differential which may be applied and consequently influences the rate of improvement which might be expected. In this connection the two sexes must be considered separately because of the fact that few males relative to the number of females are reserved for breeding in each generation. Consequently, testing equal numbers of each sex will cause a greater reduction in the selection differential for females than for males. Litter size and disproportion of sexes at weaning will also influence the size and sex composition of the test litter that will permit an optimum rate of genetic improvement.

[1] Contribution from the Division of Animal Husbandry, Experimental Farms Services, Canada Department of Agriculture, Ottawa.

* Throughout this paper the terms 'test', 'testing', 'tested', etc., refer to the measurement of carcass traits, feed economy, and gains of a sample of pigs from a litter. These pigs are slaughtered and therefore are not available for breeding.

Each additional sib tested will increase the accuracy of the test, an increase which is particularly important when heritability is low; but this increase may be more than cancelled by the resulting reduction in the selection differential, the two being more or less inversely interdependent. The extensive literature dealing with progeny testing in swine has not dealt specifically with this aspect.

In this paper the problem will be viewed primarily from the standpoint of the animal breeder in swine research. The effect of sib-testing upon the rate of genetic improvement possible when selection is solely for own performance, solely for sib performance, or simultaneously for both, will be elaborated. The application pertinent to Advanced Registry test procedure for purebred swine in Canada also will be discussed.

SELECTION ON OWN PERFORMANCE

Vigour, rate of growth, and health are major considerations in the selection of breeding stock. Without them the line may fail to maintain itself and the breeding project will be doomed to failure. Each one of these is evaluated primarily from the individual's own performance, although sib performance may play a minor role in the final decision made.

The genetic superiority of males selected for breeding on the basis of own performance (ΔS) is given by the formula

$$\Delta S = I_S G \sigma P$$

where I_S is the selection differential for the males, σP is the standard deviation within the population for the performance trait P, and G is the heritability of trait P. The genetic superiority of the females selected will be

$$\Delta D = I_D G \sigma P$$

and the average genetic gain per generation will be

$$\frac{\Delta S + \Delta D}{2}$$

The theoretical magnitude of I_S and I_D are uniquely determined by the distribution of P and by those factors which dictate what proportion (p) of the population must be retained for breeding. Values of I for different values of p are given for normally distributed populations of infinite size by Pearson (8) and may be computed readily from any table which gives the ordinates of the normal curve and the areas which they subtend. The slightly different values in small populations of 2 to 50 individuals may be calculated from Table 20 of Fisher and Yates (4).

For computational purposes in this study it is convenient to consider a herd size of 20 females and 2 males, a size of unit which is reasonably close to that usually considered desirable in swine breeding research. It may further be considered that 2 boars and 16 gilts will be reserved for breeding in each generation. This number of gilts (16) is used since Dickerson and Hazel (3) have shown that a maximum rate of progress in traits measured on own performance as well as those evaluated by sib performance will be realized if from 10 to 20 per cent of the female herd consists of the best tested sows.

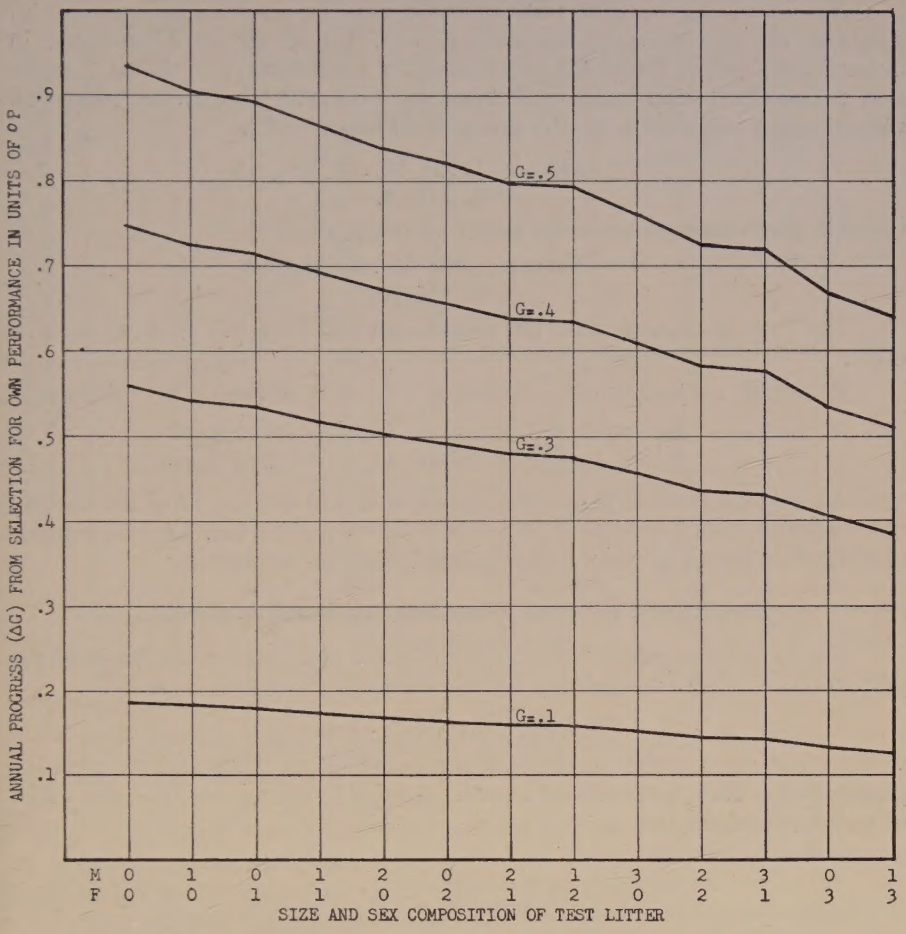

FIGURE 1. Genetic progress expected when selection is based on own performance, with 2 males and 16 gilts being reserved as replacement stock from the 20 litters farrowed annually.

If an average of 8 pigs, 4 of each sex, are weaned per litter, the population size from which selection may be made for own performance will be 80 males and 80 females when no pigs are tested. If two pigs of each sex are tested per litter the population size for this selection is automatically reduced to 40 males and 40 females. The expected rates of genetic improvement per generation obtainable with different values of G (heritability) and for varying size and sex composition of the test litters are illustrated by Figure 1.

It is obvious that the optimum rate of improvement for own performance is realized when no pigs are sacrificed in a slaughter test. The rate of improvement is gradually reduced as the number of test pigs is increased. Since the number of males required for breeding is relatively small the slaughter of males causes a lower reduction in rate of improvement than does the slaughter of females.

Age at market weight (200 pounds) may be used as an example of selection on own performance with $G = .30$ and $\sigma P = 15.6$ days, in accord with values found for the Canadian Yorkshire (5). With 2 males and 2 females tested from each litter $I_S = 1.955$ and $I_D = .946$ (4). Genetic gain expected from the selection of boars will be

$$\Delta S = 1.955 \times .30 \times 15.6$$
$$= 9.1 \text{ days.}$$

Genetic gain expected from the selection of gilts will be

$$\Delta D = .946 \times .30 \times 15.6$$
$$= 4.4 \text{ days.}$$

The average genetic gain per generation will be $\frac{1}{2}(9.1 + 4.4) = 6.8$ days.

If no pigs are tested $I_S = 2.338$ and $I_D = 1.401$ (8). In this case

$$\Delta S = 2.338 \times .30 \times 15.6 = 11.0 \text{ days}$$
$$\Delta D = 1.401 \times .30 \times 15.6 = 6.6 \text{ days}$$

with an average genetic gain per generation of 8.8 days. Thus the testing of no pigs permits 2.0 days or 29 per cent faster genetic gain in each generation than is the case when 2 males and 2 females are tested.

SELECTION ON THE BASIS OF SIB PERFORMANCE

The genetic superiority of breeding stock reserved on the basis of sib performance alone is estimated by the formula

$$\Delta G = I\sqrt{G}\sigma P \cdot r_{00}$$

where r_{00} is the correlation between the genotype of a pig and the average phenotype of its n tested litter mates. Lush (7) has shown that the value of r_{00} is equivalent to

$$\frac{1}{2}\sqrt{\frac{nG}{1 + (n - 1)t}}$$

with t being the observed correlation between litter mates. This may be rewritten as

$$\frac{1}{2}\sqrt{\frac{nG}{E + nM + \frac{G}{2}(n + 1)}}$$

where G is the fraction of the total variance that is genic, M the fraction of the total variance due to non-genic differences between litters, and E the fraction of the total variance due to non-genic differences between litter mates.

Values of this fraction for different values of G, M, and E and for different numbers of pigs tested are given in Figure 2. This figure illustrates that from the standpoint of accuracy the larger size of test litter is desirable. This is particularly true if the performance trait concerned is of low heritability. But the magnitude of M also contributes importantly to the predictive value of the test. If M is large and G (heritability) low, little advantage accrues from testing more than 4 pigs.

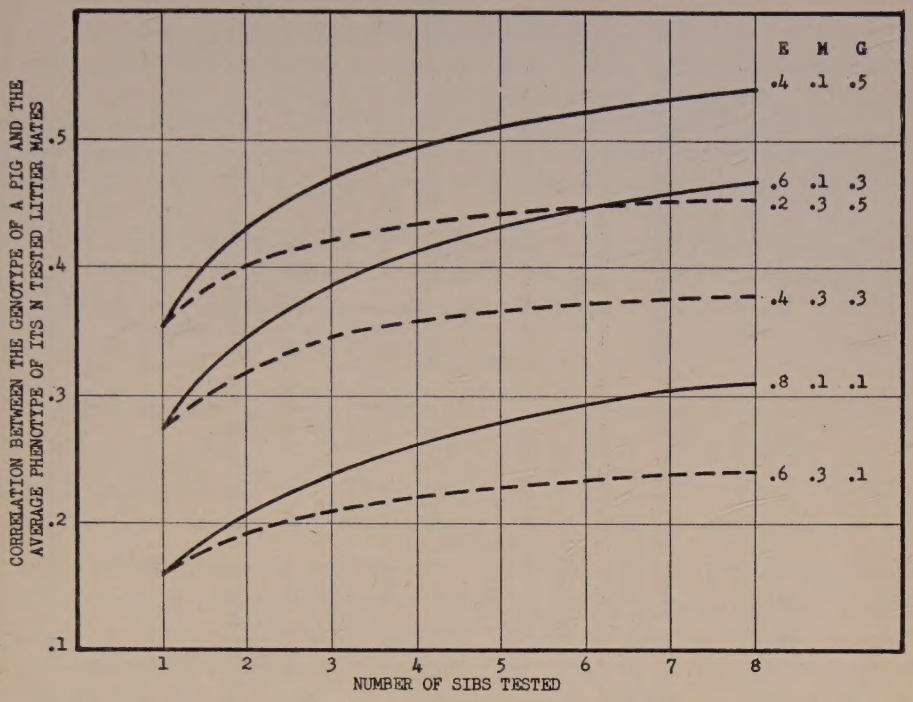

FIGURE 2. Increase in the predictive value of the sib test as the number of sibs tested varies from one to eight.

The preceding graph describes the situation when the test pigs are chosen at random. Lush (7) has pointed out that if the test pigs are selected so as to get a representative sample the correlation will be higher when n is small but would increase less rapidly with an increase in n. Conversely, if the best pigs in the litter are chosen for test the correlation will be lower but would rise more rapidly with increasing n.

The value of I will depend upon the number of litters tested, selection for any trait on the basis of sib performance reducing the effective population size to the number of litter averages available. If all litters are tested there will be 20 averages for each of the different carcass traits concerned, and replacement stock may be reserved from those litters giving the highest averages.

Considering such a trait as carcass length, the 2 boars required may be reserved from the two litters whose test pigs gave the greatest average length. Theoretically this may be done when as many as three males have been slaughtered from each litter. The proportion of the male population saved (p) will be 2/20 which provides a selection differential for sires (I_S) of 1.64. But the selection differential for females will be determined by the number of females tested from each litter. If no females are tested the four top litters could theoretically contribute the 16 gilts required. But if 1, 2, or 3 females are tested per litter the minimum values of p will be 6/20, 8/20, and 16/20 respectively. Thus the maximum values for I_D will be 1.33, 1.11, 0.93, and 0.33 depending upon whether 0, 1, 2, or 3 females have been slaughtered from each litter.

TABLE 1.—POSSIBLE RATES OF GENETIC IMPROVEMENT WHEN VARYING NUMBERS OF EACH SEX ARE SLAUGHTERED AND SELECTION IS BASED ON OWN PERFORMANCE OR ON SIB PERFORMANCE

Selection based on	Heritability (G)	Composition of test litter (M/F)												
		2/2	1/0	0/1	2/0	1/1	0/2	3/0	2/1	1/2	0/3	3/1	1/3	0/0*
Own performance	Any value	100	125.0	123.1	115.7	119.1	113.2	104.8	109.9	109.3	92.1	99.1	88.1	128.9
Sib performance	.5	100	82.8	76.7	100.8	93.3	87.1	110.0	101.9	95.1	73.0	107.1	76.8	126.0
	.4	100	79.8	73.8	98.9	91.6	85.5	109.1	101.0	94.4	72.5	107.1	76.8	128.5
	.3	100	76.5	70.8	96.8	89.6	83.7	108.2	100.2	93.5	71.8	107.1	76.8	130.5
	.1	100	69.7	64.5	91.9	85.0	79.4	105.8	98.0	91.4	70.2	107.1	76.8	137.5

* For this column the assumption is made that no pigs are slaughtered, but by use of X-rays, for example, the required carcass measurements are available for each of the pigs (8) in the litter.

Combining the values of r_{00} from Figure 2 with the values of I_S and I_D appropriate to the number of each sex tested per litter permits computation of the expected rates of genetic improvement per generation. These are shown in Figure 3. Optimum improvement is realized when 3 males and no females are sacrificed from each litter. The addition of a single female, while contributing to the accuracy of the test, actually reduces the rate of progress.

Carcass length, a trait for which selection is based on sib performance, has a heritability of .40 and a standard deviation (σP) of .84 inches (5). If 2 males and 2 females are tested from each litter $I_S = 1.64$ and $I_D = 0.93$ (4). Using the formula

$$\Delta G = I\sqrt{G}\sigma P\ r_{00}$$

the genetic gain expected per generation from selection of boars will be

$$\Delta S = 1.64 \times .6324 \times .84 \times .459 = .40 \text{ inches}$$

and from the selection of gilts

$$\Delta D = 0.93 \times .6324 \times .84 \times .459 = .23 \text{ inches.}$$

This provides an average gain per generation of .31 inches in carcass length.

If the test litter consists of 3 males and no females $I_S = 1.64$ but $I_D = 1.33$. Utilizing these values in the above formula provides values of .38 inches for ΔS and .31 inches for ΔD, with an average genetic gain per generation of .34 inches. This represents an increase of 9 per cent over that attained when 2 males and 2 females are tested.

SIMULTANEOUS SELECTION ON BOTH OWN AND SIB PERFORMANCE

Seldom in swine improvement will selection be directed towards improvement of a single performance trait. Instead the breeder will attempt to make the optimum improvement in net merit which is a combination of some factors measured by individual performance and other factors measured by sib performance (carcass traits). To achieve this requires some compromise on the size and sex composition of the test litter since, as may be seen by comparing Figures 1 and 3, the test litter that is optimum for the one is far from optimum for the other. This comparison is facilitated by the figures given in Table 1. For purposes of this table a test litter consisting of 2 males and 2 females was used as the standard and the rate of genetic progress possible with selection based on own or on sib performance when various combinations of the two sexes are slaughtered is compared with this standard.

If sib performance and own performance receive approximately equal emphasis in selection, then the testing of 4 pigs from a litter is not compatible with the maximum rate of genetic improvement even in the case where the traits concerned are of low heritability. Under such conditions the testing of 3 pigs or even 2 pigs will, depending upon the sexes sacrificed, give the maximum returns. Three pigs might be considered as the optimum size of test litter since the accidental loss of one out of three test pigs would not have as marked an effect on the predictive value of the test as would the loss of one from a test litter of two.

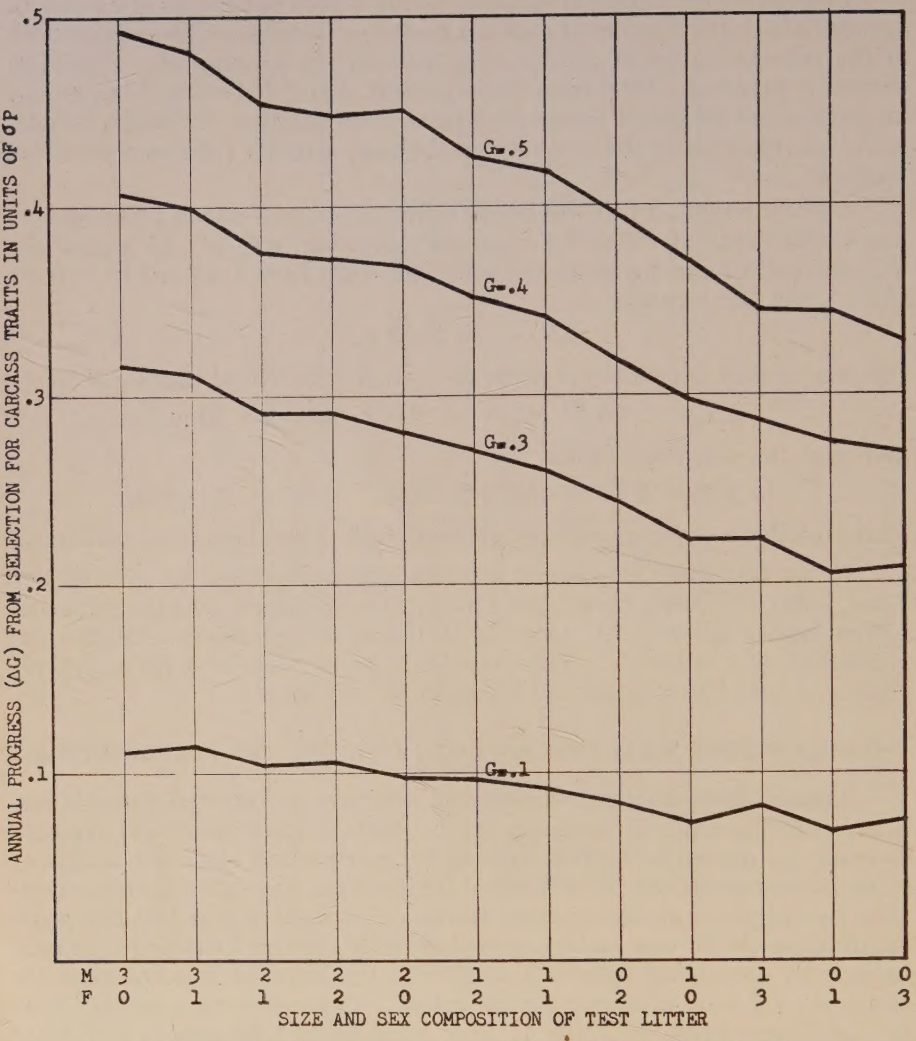
ANNUAL PROGRESS (ΔG) FROM SELECTION FOR CARCASS TRAITS IN UNITS OF σP
.5
.4
.3
.2
.1
G=.5
G=.4
G=.3
G=.1
M 3 3 2 2 2 1 1 0 1 1 0 0
F 0 1 1 2 0 2 1 2 0 3 1 3
SIZE AND SEX COMPOSITION OF TEST LITTER

FIGURE 3. Genetic progress expected when selection is based on sib performance (litter average) and 2 males and 16 gilts are reserved as replacement stock from the 20 litters farrowed and tested annually.

For computation of the last column of Table 1 the assumption was made that all pigs (8) of each litter were tested but none slaughtered. The probe technique for fat measurements (6) and use of X-rays (11) for obtaining measurements of backfat and skeletal dimensions are methods by which certain carcass data may be obtained without the sacrifice of test animals.

DISCUSSION

The most suitable size and sex composition of a test litter will be determined, in practice, by the actual sex balance obtained in the litters to be tested and upon the size of those litters. Computations in the preceding

sections were based upon a litter size of 8 pigs balanced as to sex. Smaller litter size would accentuate the desirability of fewer pigs in the test litter while a preponderance of one sex would permit some adjustment of the sexes included on test. Comparison of test litters of differing sex proportions is facilitated by the use of correction factors computed from the measurements of over 12,000 Yorkshire hogs (5). Similar correction factors have been employed in Denmark for many years to adjust test results for disproportionacies in sex (1).

The relative emphasis placed on own and sib performance in selection will also influence the optimum constitution of the test litter. If own performance (rate of growth, visual appearance, vigour, strength of feet and legs, type) is of paramount importance a slaughter test will be of little value and may be dispensed with entirely. But if carcass quality is an important criterion the optimum rate of improvement will be realized by slaughtering a minimum of 2 and a maximum of 3 pigs per litter to provide the required carcass measurements. If heritability of the trait is low there may be some justification for a test litter of 4 pigs, 3 males and one female. In another study (5) the author has shown, however, that heritabilities of the important carcass traits in the Canadian Yorkshire are in excess of .3, a finding that is consistent with the results reported by other workers for several different breeds of swine (2, 7, 10).

The advantage of the smaller size of test litter is further enhanced if non-genic differences between litters (M) contribute importantly to the total variance in the population. This situation, however, does not appear to exist except for rate of growth (2), and individual merit rather than sib performance may be used as the selection criterion for this trait.

It must be recognized that selection on the basis of sib performance is limited to the tested litters; i.e., the population size for selection on the basis of carcass merit is equivalent to the number of litters for which such information is available. This fact is undoubtedly appreciated by all engaged in swine research, but it is not generally understood by purebred swine breeders who, if they test, do so sporadically and with a minimum number of litters at a time.

Economically this may be a sound approach. Such breeders are primarily interested in the sale of breeding stock and their supply of potential sale stock would be depleted by wholesale testing. However, the practice is not conducive to breed improvement in carcass merit or economy of gain as an insufficient number of litters is tested by any one breeder to permit within herd selection for these traits.

Reduction in the required size of test litter might encourage greater use of Advanced Registry by individual breeders and in this way contribute to more rapid genetic improvement of Canadian swine.

Assumptions were made in this study concerning the size of herd involved and the number of breeding stock saved in each generation, but the conclusions reached are directly applicable to herds of larger or smaller size or to instances where a lesser number of boars or gilts are reserved for breeding.

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CONCENTRATE PELLETS AND WHOLE GRAIN AS A METHOD OF FEEDING LAYING HENS

J. B. O'Neil

Department of Poultry Husbandry, University of Saskatchewan, Saskatoon

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ABSTRACT

A new method of feeding laying hens which is based on the feeding of concentrate in pelleted form and mixed with whole grains is described. The advantages of this method are: (1) no chopping of the grains; (2) ease of mixing, and (3) elimination of the hand feeding of whole grain. A laying trial of 280 days indicates that the production characteristics of the hens, when fed in the above manner, are equal to those obtained from the usual methods of feeding. Limited data on hatchability show comparable results.

INTRODUCTION

Through the years, various methods of feeding laying hens have been tried and even though each has its advantages and disadvantages the results would indicate that they are comparable. It would seem, then, that the form in which the feed is given to the birds is immaterial, as long as the diet is adequate. A comparison of the different methods of feeding are listed in text-books on poultry feeding and need not be reviewed here.

The system used in any particular area will be dependent upon local conditions and the type of poultry farming practised. Hill (1) has pointed out, as an example, the interest in all-mash rations for layers because of its adaptability to efficiency of labour. In Saskatchewan, the bulk of the laying stock are small flock enterprises and the returns from these flocks represent only a minor portion of the farm income. As well, nearly all of these farms produce sufficient grain to meet the requirements of the birds. For this reason, the use of commercial concentrate mashes is a very practical way of providing a balanced diet. Such a method has two disadvantages, namely, having to chop the grain, and having to mix the chop with the concentrate mash. One disadvantage of the mash-grain system is the necessity of feeding the whole grain portion of the diet, usually twice a day. As well, there is the tendency to overfeed the whole grain. A new method of feeding has been tried, the results of which form the basis of this report. In place of the concentrate in mash form, this method utilizes the concentrate as pellets to be mixed with whole grains, including that portion which would normally be fed as the whole grains morning and evening. Thus, in principle it is the same as an all-mash ration, except that the form in which it is fed differs materially.

MATERIAL AND METHODS

Two hatches of cross-bred pullets (New Hampshire × Barred Plymouth Rock) were allotted at random to eight adjoining pens in groups of 47 birds each. These birds were housed in early September and were fed a mash-grain diet until 10 days before the commencement of the test.

During this 10-day period, the pullets were gradually changed over to the experimental diets. Four different methods of feeding were compared. The control group was fed mash ad libitum and a mixture of whole grains (2 parts wheat and 1 part oats) twice a day in amounts to equal the mash consumption. Group 2 differed from the control in that they received the whole grain only once a day, in the late afternoon. Group 3 received an all-mash ration. The mash of these three groups was a commercial concentrate mash which was mixed with equal proportions of ground wheat, oats and barley. In the all-mash group, the whole grain portion of the diet was ground and incorporated in equal proportions with the mash. The ratio of the concentrate to grains, either ground or ground and whole, was 1 : 7 in all cases. The fourth group received a mixture of concentrate pellets and whole grains at the rate of 1 : 7. This was fed ad libitum. Each treatment was duplicated. The experimental period was 280 days, from November 19, 1951, to August 25, 1952.

All birds were trap-nested five days per week. Egg size was determined by weighing all the eggs individually for five consecutive days in each 4-week period. Body weights were recorded once every four weeks. Feed consumption was calculated on a bird day basis at the end of each 4-week period with due allowance being made for mortality. Feed efficiency (pounds of feed consumed per dozen eggs produced) was calculated from the appropriate data.

Since the hens were not mated, data on hatchability according to the method of feeding were not available. However, a similar trial is now in progress and as these four feeding methods constitute part of this test in which some hatchability data has been recorded, it is of interest to incorporate these results in this paper. Two hatches from triplicate pens of 23 birds each form the basis of this comparison.

EXPERIMENTAL RESULTS

A summary of the egg production characteristics of the birds according to treatment is listed in Table 1.

The percentage production was quite similar for the four treatments, indicating that the various forms in which the feed was given to the birds were immaterial. While the control group was slightly higher in production than either the all-mash or concentrate pellets and grain, the difference is not significant. Average egg size was uniformly good throughout, there being no difference between treatments. Body weights were similar for three of the groups. Those receiving the all-mash diet were on the average 129.1 grams less, and this is a reflection of a somewhat lowered feed consumption.

The percentage fertile hatch was high in all cases. The all-mash group had the highest hatchability and this might be accounted for by the fact that the hens had a more balanced diet. The other groups received whole grains as part of their total intake and some of these hens could consume more than their share of grain with a corresponding reduction in mash or pellet consumption. The hens receiving concentrate pellets and whole grain had as good hatchability as the remaining two groups.

TABLE 1.—PRODUCTION CHARACTERISTICS AND HATCHABILITY ACCORDING TO THE METHOD OF FEEDING

Treatment	Per cent production	Average egg size	Average body weight	Average daily consumption	Pounds feed per dozen eggs	Mortality	Fertile hatch (1953)
		gm.	gm.	gm.		%	%
Mash+grain twice a day	60	64	2822	130	5.7	8	89
Mash+grain once a day	60	63	2824	134	5.9	8	83
All mash	59	62	2705	126	5.7	9	93
Concentrate pellets and whole grain	58	64	2857	134	6.1	9	88

TABLE 2.—SEASONAL EFFECT ON PRODUCTION CHARACTERISTICS ACCORDING TO THE METHOD OF FEEDING

Treatment	Per cent production			Average changes in body weight (gm.)		
	Nov. 19-Mar. 10	Mar. 10-Aug. 25	Nov. 19-Aug. 25	Nov. 19-Mar. 10	Mar. 10-Aug. 25	Nov. 19-Aug. 25
Mash+grain twice a day	67	55	60	+168	− 170	− 2
Mash+grain once a day	67	55	60	+246	− 216	+ 30
All mash	68	53	59	+126	− 282	−156
Concentrate pellets and whole grain	60	57	58	+228	− 86	+142

Treatment	Average daily consumption (gm.)			Pound feed per dozen eggs produced		
	Nov. 19-Mar. 10	Mar. 10-Aug. 25	Nov. 19-Aug. 25	Nov. 19-Mar. 10	Mar. 10-Aug. 25	Nov. 19-Aug. 25
Mash+grain twice a day	145	118	130	5.7	5.6	5.7
Mash+grain once a day	147	124	134	5.8	6.0	5.9
All mash	140	115	126	5.4	5.8	5.7
Concentrate pellets and whole grain	141	130	134	6.2	6.1	6.1

The response of the birds as listed in Table 1 is based on the results obtained throughout the entire trial. Whether or not the form of feeding had any effect upon either winter or summer production characteristics is not indicated. In order to determine the response of the layers to the method of feeding according to season, Table 2 divides the data into two sections. The first portion is the results to March 10, 1952, and the second from the date to the end of the test. The division was made at March 10 for several reasons. Body weights were at their peak, egg production was just approaching maximum and the weather was in a transition period between winter and summer.

The winter egg production for all pens except those receiving the pellets and whole grain is very similar. The lower production in this latter group is due, at least in part, to a neck moult caused by too rapid a change from the conventional method of feeding to the pellets and whole grain. In contrast, the production for the remainder of the trial is comparable, with the pellet and grain group being slightly higher than the others. The drop in production during the latter part of the year is much less pronounced in the pellet and grain group. The changes in body weight are interesting in that they follow the trend in egg production. During the winter months the birds in all groups increased their weight according to their rate of lay. The all-mash did not produce as great a gain in body weight as those receiving whole grains in their diet. During the latter part of the production year, losses in weight were recorded in all groups. The pellet and grain group declined to a lesser degree than the others and also had the highest production. The change in weight throughout the trial is also listed. The all-mash group along with the control weighed less at the end of the trial than at the beginning, whereas the others increased the weight, particularly the pellet and grain group. At the commencement of the test, the greatest average difference in weight between any two groups was only 14 grams. No supplementary feeding was used.

Feed consumption during the winter months averaged 5 ounces per bird. While higher than the usual "4 ounces per bird per day" rule, consideration must be given to the size of hen. In this case, they averaged very close to 6 pounds. The consumption per bird declined during the warmer months but was still over the 4 ounces per bird per day. The all-mash and pellet and grain groups consumed the least and the most, respectively, and this is in the same order as production for the same period of time. The feed efficiency is comparable for both seasons for all groups. The all-mash were the most efficient during the winter months, whereas the control group required the least amount of feed to produce a dozen eggs during the warmer part of the year. The pellet and grain group were about the same throughout the year. The efficiency figures are influenced by the changes in body weight as well as by production.

Any method of feeding has both advantages and disadvantages. This new method, which has been tested, has the advantage of not requiring the chopping of any grain, is more easily mixed than concentrate mash and chop, eliminates the hand feeding of whole grain once or twice a day, and the pellets can be measured either by weight or by measure since the weight per bushel is very similar to a mixture of whole grains such as used in this

trial. These advantages are to a slight degree offset by the cost of having the concentrate mash pelleted. Further, the results indicate a slightly less efficient use of the feed but better maintenance of body weight throughout the year.

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A STUDY OF THE EFFECTS OF TEMPERATURE AND OTHER FACTORS UPON THE GERMINATION OF VEGETABLE CROPS

I. SWEET CORN[1]

By W. E. Torfason and I. L. Nonnecke[2]

Experimental Station, Lethbridge, Alberta

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ABSTRACT

A series of trials was conducted during 1950 and 1951 to study the effects of temperature, as well as the effects of the nature of the germinating medium and of the duration of exposure, upon the germination of one hybrid and three open-pollinated varieties of sweet corn. The results indicated that germination of sweet corn seed was seriously inhibited by temperatures of 10° C. or less, with no significant differences between the effects of 10° C. and the lower temperatures. Germination in soil was lower than in vermiculite, particularly at low temperatures, indicating that other factors, such as soil pathogens, aeration and compactness, play an important role in limiting germination in cold soil. The duration of exposure was a limiting factor only at the lower temperatures. Although significant varietal differences were observed, they could not be attributed to any differences in cold resistance, and should be considered as being related to the viability and the maturity of the particular seed lots used.

INTRODUCTION

Sweet corn is one of the most important of the canning crops grown in southern Alberta. The acreage producing this crop is increasing annually and, with the present progress in irrigation development, further increases are expected.

Stands of sweet corn are often observed to be poor, especially in seasons when cold, wet soil conditions prevail during the germination period. Such observations have raised two important questions: (1) Is the germinating ability of sweet corn inhibited or destroyed by low soil temperatures ? and (2) Are attacks by soil pathogens, upon the elongating coleoptile, responsible for reducing the final stands of sweet corn in the field ?

The species *Zea Mays* L. is usually considered to be a warm season plant and, therefore, its development is best under conditions of high summer temperatures. The reasons underlying poor germination at low temperatures are, however, little understood. The project reported here was initiated to study the effects of exposure to low temperatures, in several media, upon the germination of certain varieties of sweet corn.

LITERATURE REVIEW

The role of enzymes in initiating embryo development and the influences of climatic factors generally on seed germination, have been discussed by Meyer and Anderson (4). These authors state, with reference to corn, that the germination temperature is optimum at 30° C. and varies through 5° to 45° C. Magoon and Culpepper (3) have established a

[1] Joint contribution from the Division of Horticulture, Experimental Farms Service, Canada Department of Agriculture, Ottawa, and the Department of Plant Science, University of Alberta, Edmonton; a thesis submitted to the Graduate School, University of Alberta, Edmonton, Alberta, in a partial fulfilment of the requirements for the Degree of Master of Science.

[2] Horticulturist, and Head of Horticulture Section, respectively.

minimum soil temperature range of 7° to 13° C. for sweet corn and have reviewed papers by Lehenbauer, and by Erwin, that support their observations.

A number of investigators, including Tatum and Zuber (8), and Vander Meulen and Henke (9), have emphasized the importance of seed coat injury in permitting the entry of soil pathogens into the seed and destroying its ability to germinate.

Rush and Neal (7) advanced the theory that germination of corn, at low temperatures, was significantly affected by the degree of maturity at which the seed was harvested. They reported that mature seed germinated much better than seed which was somewhat less mature when harvested. Seed coat injury did not appear to be of major significance in determining stands of corn at low temperatures.

That cold hardiness of corn is affected by the genetical constitution has been emphasized by a number of workers. Pinnell (6) and Mortimer (5), in separate works, concluded that cold hardiness was inherited in crosses, and that the female parent played the primary role in determining the differences. This indicates that a form of cytoplasmic inheritance may be involved. Haskell (1) observed that genetical constitution, temperature, duration of exposure, and the nature of the germination medium all significantly affected the final germination of sweet corn.

MATERIALS AND METHODS

The following variables were considered in this study:

1. *Temperature*—Controlled temperature chambers were used at the Science Service Laboratories, Lethbridge, in 1950, and at the Experimental Station, Lethbridge, in 1951. In both units, temperatures of 5°, 10° and 15° C. were maintained throughout the duration of exposure. These temperatures could not be duplicated at the University of Alberta during the winter of 1950-51; therefore, the trial was conducted using temperatures of 1.7°, 10°, and 18.3° C.

2. *Germinating Media*—Seed was sown in three different media:

(*a*) Lethbridge brown silt loam from the horticultural area of the Experimental Station.
(*b*) Parkland black loam (Malmo silty clay loam) from the Parkland Farm of the University of Alberta.
(*c*) Vermiculite—sterile heat-expanded particles of mica, sold under the trade name of "Zonolite".

Neither of the soils had been used for growing corn for a number of years.

3. *Duration of Exposure*—The seed was exposed in each of the above media and at each of the above temperatures for periods of 10, 20 and 30 days' duration.

4. *Varieties*—Three open pollinated varieties (Altagold, Dorinny, and Golden Early Market) and one hybrid (Carmelcross) were subjected to all combinations of temperature, media, and duration of exposure.

In the controlled temperature chambers, the seed was sown in flats and covered with approximately one inch of the appropriate medium. The media were kept moist as required. Seedings were spaced at 10-day intervals so that all exposure periods would be completed at the same time.

After the completion of exposure, the flats were removed from the controlled temperature chambers and transferred to the field, or to the greenhouse, for the completion of germination. When transferred to the field, the seeds were removed from the flats and set into the soil at approximately the same depth as they were in the flats.

The trials were set up as split plot factorials, with four replications. Each replication consisted of nine whole plots made up of all combinations of the three temperatures and the three media. The location of the whole plots was at random within each replication. Each flat corresponded to a single whole plot.

Each whole plot, in turn, consisted of twelve sub-plots (rows) made up of all combinations of the three durations of exposure and the four varieties. The position of each sub-plot within each whole plot was at random with a different randomization in each case. Each sub-plot consisted of 25 seeds.

In order to facilitate setting out the field trial the sub-plots were transferred to the field in the same rotation as they appeared in the flats. In the field, the sub-plots became single 25-foot rows, spaced three feet apart, with the seeds placed at intervals of approximately one foot.

Because of labour shortages, and the time required to seed the sub-plots as indicated above, the 1951 greenhouse trial was laid out in a different manner. Replication was accomplished by seeding varieties being subjected to the same treatment in quadruplicate rows. The previous trials had indicated that each medium was relatively uniform, and that randomization could be restricted.

Germination data were recorded as percentages, and were transformed for analysis by means of the angular transformation (2).

CLIMATIC INFLUENCES

In 1950, the transfer to the field was made into relatively dry soil, under warm weather conditions. The entire plot area was sprinkled with about one inch of water immediately after the transfer, giving almost ideal conditions for the completion of germination.

In 1951, on the other hand, the soil was very wet and low temperatures persisted for an extended period. Four days after the transfer was made (June 26), a heavy snowfall occurred. A month later, observations were made, and it was considered that the low temperatures had nullified the effects of the previous temperature treatments. In view of these conditions, it was decided to abandon the trial.

In both greenhouse trials, the temperatures in the greenhouses were relatively low and could not be altered appreciably because of the presence of other plants in the greenhouses. This condition resulted in slow germination, and may have resulted in germination rates that were lower than normal, particularly in the two soils.

RESULTS

In the 1950 Field Trial, nearly all the seed exposed to the temperature of 15° C. had germinated before being transferred to the field. It was, therefore, necessary to transplant these plants. As a result of the trans-

planting operation, considerable losses were incurred. Counts were made of the initial germination and a comparison was made with the final stands. The larger figure of the two was taken to be the final germination rate for purposes of analysis.

At silking time, no consistent differences in maturity could be detected between treatments within varieties. There were, however, normal maturity variations between the early and mid-season varieties.

Plants from the lower temperature treatments were generally shorter than those from the 15° C. treatment, but this difference was not consistent in all cases. The number of tillers per plant varied within treatments but there were no consistent differences from one treatment to another.

Despite differences in the conditions prevailing for the different trials certain trends are quite apparent.

The uniformity of treatment behaviour from one trial to the other was established by analysis. In all instances, temperature differences were significant, while in two of the three cases media were significant. Varieties, too, differed significantly in all three trials. The duration of exposure was significant to the 5 per cent level only in the 1950 Field Trial.

TABLE 1.—MEAN GERMINATION RATES (IN DEGREES) OF SWEET CORN FOR EACH TEMPERATURE TREATMENT—ALL TRIALS

Temperature (° C.)	Field trial 1950	Greenhouse trial 1950-51	Greenhouse trial 1951	
			Complete trial	Vermiculite only
1.7	—	10.7	—	—
5.0	31.7	—	26.1	42.1
10.0	30.7	25.2	35.3	61.2
15.0	44.7	—	56.7	71.3
18.3	—	58.1	—	—
L.S.D.	± 9.8	± 22.6	± 12.2	± 4.3

TABLE 2.—MEAN GERMINATION RATES (IN DEGREES) OF SWEET CORN SOWN IN DIFFERENT MEDIA—ALL TRIALS

Medium	Field trial 1950	Greenhouse trial 1950-51*	Greenhouse trial 1951
Vermiculite	55.1	45.95	58.2
Parkland Soil	23.1	24.69	30.5
Lethbridge Soil	29.0	23.33	29.3
	± 9.8	± 22.63	± 12.2

* Carried to two significant figures to show that the difference between germination in Vermiculite and Lethbridge Soil (22.62) approaches the L.S.D.

TABLE 3.—MEAN GERMINATION RATES (IN DEGREES) OF FOUR SWEET CORN VARIETIES—ALL TRIALS

Variety	Field trial 1950	Greenhouse trial 1950-51	Greenhouse trial 1951	
			Complete trial	Vermiculite only
Altagold	42.8	31.5	50.2	65.9
Carmelcross	37.4	38.2	36.6	60.5
Dorinny	36.3	23.6	30.0	46.2
Golden Early Market	26.4	32.1	40.5	60.3
	± 7.5	± 4.5	± 6.6	± 3.7

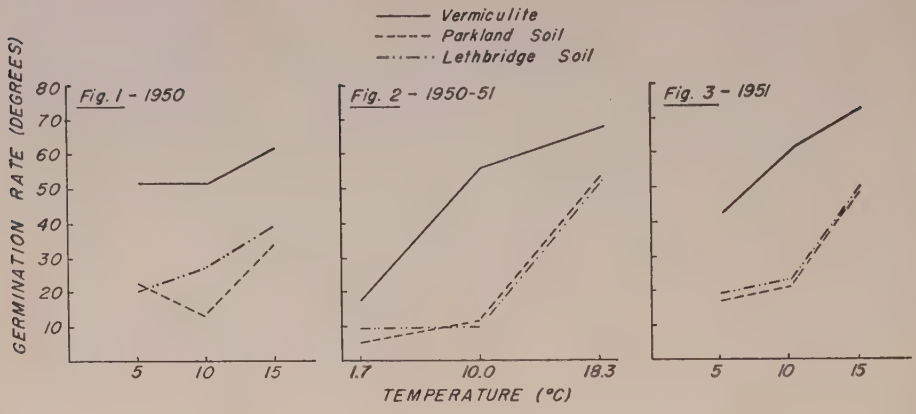
Dealing first with the significant main effects, the differences due to temperature treatment may be observed in Table 1 in which the mean germination rates are given (in degrees) for each temperature for the different trials. The least significant difference for each trial is also listed, and when this is applied to the means we find that the germination rate of 10° C. is significantly lower than that at the next highest temperature. On the other hand, germination at the lowest temperature does not differ significantly from that at 10° C. Where germination in vermiculite alone is considered, each treatment differs significantly from each other treatment.

Treatment differences due to media are shown in Table 2. In both 1950 and 1951 germination in vermiculite was significantly greater than in either of the soils, with no apparent difference between the germination in soils. In the 1950-51 trial, the differences are not significant. However, the difference between germination in vermiculite and in Lethbridge soil approaches the 5 per cent level of significance.

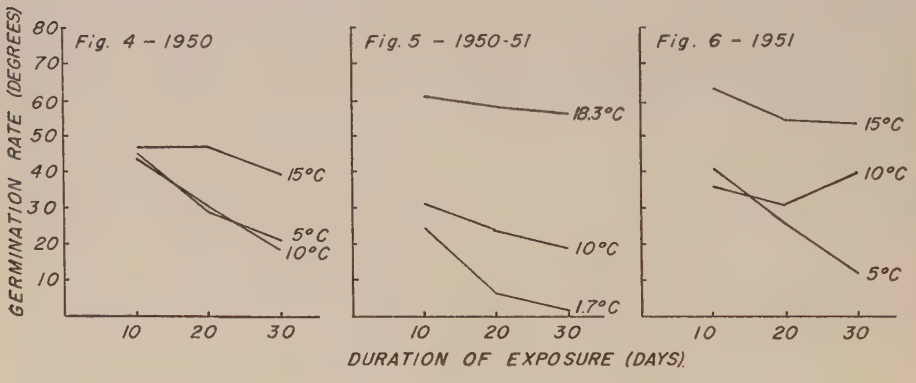
Table 3 lists the mean germination rates for each of the four varieties as they appeared in the different trials. In 1950, Golden Early Market germinated at a significantly lower rate than any of the other three varieties, which did not differ significantly from one another. In 1950-51, Carmelcross and Dorinny were significantly higher and lower, respectively, than the two remaining varieties. And in 1951, Altagold was significantly higher, Dorinny significantly lower than all others. Considering vermiculite alone, in 1951, it is observed that these two varieties occupied the same positions as in the complete trial.

The interaction between temperature and media, as illustrated graphically in Figures 1, 2 and 3, indicates the differential response of sweet corn seed germinating in the various media at the different temperatures. Figures 2 and 3 show clearly the effect of the soils in inhibiting germination at temperatures of 10° C. or lower.

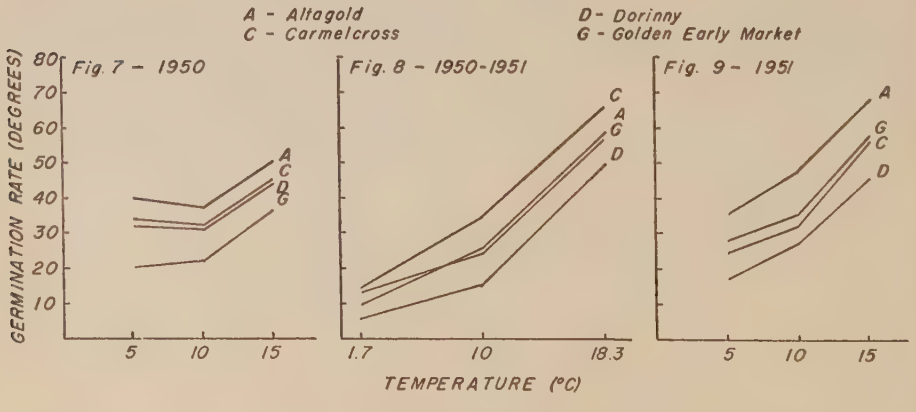
That the effect of temperature upon germination was altered by increasing the duration of exposure is borne out by the significance of that interaction. It may be observed in Figures 4, 5 and 6 that germination at



FIGURES 1-3. The effect of temperature upon the germination of sweet corn in different media.



FIGURES 4-6. The effects of the duration of exposure to different temperatures upon the germination of sweet corn.



FIGURES 7-9. The effects of temperature upon the germination of one hybrid and three open-pollinated varieties of sweet corn.

15° C. or 18.3° C. was only slightly affected by the duration of exposure, whereas at the lower temperatures germination decreased more sharply. The effect of duration of exposure upon germination at 10° C. (Figure 6) cannot be explained.

Probably the most interesting of the interactions is one which was insignificant in all trials. The interaction between temperature and variety, as illustrated graphically in Figures 7, 8, and 9, indicates that all four varieties reacted similarly to temperature treatment. All three graphs show roughly parallel curves for the varieties.

DISCUSSION OF RESULTS

These trials have shown that germination of sweet corn at 10° C. was significantly lower than at the higher temperatures studied, and also that the differences between the effects of the 10° C. and lower temperatures, while indicated, were not significant. The minimum growth temperature for sweet corn must, therefore, be between 10° and 15° C. This conclusion agrees with those of other workers, as reviewed earlier. The lower temperatures (5° and 10° C.) might be useful in evaluating the cold hardiness of sweet corn inbreds, as was suggested by Pinnell (6) and Mortimer (5).

Haskell's (1) observation that the nature of the germinating medium affected germination was confirmed in this study. Germination was much lower in soils than in vermiculite, especially at the lower temperatures. This observation suggests that the reduction in germination was, as reported by Haskell (1), due partly to the direct effects of cold, and partly to attacks by fungal organisms. In this connection, seed exposed at 10° C. showed a greater incidence of moulded kernels than did the seed exposed at 5° C. (no actual counts were made). It seems, therefore, that the reduction in germination at 5° C. was due largely to the destruction of the embryo by low temperature, and at 10° C. by the penetration of soil pathogens into slightly damaged seeds and the slowly developing coleoptiles. The compactness and poor aeration of the soils were probably responsible for some reduction in germination.

Although the duration of exposure was apparently not of importance in each complete trial, there can be no doubt that it was important at the lower temperatures [Haskell (1)].

The observations made by Haskell (1), Pinnell (6) and Mortimer (5), dealing with the effect of genetical constitution upon germination were not borne out in this study. There were significant differences between the mean germination rates of the varieties. It was found, however, that there was no apparent difference in the response of the varieties to the temperature treatments. This latter observation suggests that the varietal differences noted were due primarily to differences in the viability the individual seed lots used. The differences in viability could have been due to differences in the maturity of the seed at time of harvest, as suggested by Rush and Neal (7). It should also be considered that the varieties used here were all essentially short-seasoned in nature, and that a long-seasoned variety, such as Iochief, Lincoln, or Lee, may have reacted differently to cold treatment.

CONCLUSIONS

1. Temperatures of 10° C. or lower caused significant reductions in the germination of sweet corn.

2. Germination in soil was significantly lower than in vermiculite, particularly at the lower temperatures, suggesting the importance of the role of soil pathogens and poor aeration in limiting the stands of sweet corn at low germinating temperatures.

3. The longer durations of exposure to the lower soil temperatures caused marked reduction in the germination of sweet corn.

4. Varietal differences were believed to be due to differences in the viability of the individual seed lots. There was no real difference in varietal response to temperature treatment.

ACKNOWLEDGMENTS

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EFFECTS OF VARIOUS LEVELS OF NITROGEN, PHOSPHORUS, AND POTASSIUM IN NUTRIENT SOLUTION, ON THE FECUNDITY OF THE TWO-SPOTTED SPIDER MITE, *TETRANYCHUS BIMACULATUS* HARVEY (ACARINA: TETRANYCHIDAE) REARED ON CUCUMBER[1]

E. J. LeRoux[2]

Fruit Insect Section, Science Service Laboratory, Harrow, Ontario

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ABSTRACT

Studies were conducted on the effects of various levels of nitrogen, phosphorus, and potassium on the fecundity of the two-spotted spider mite, *Tetranychus bimaculatus* Harvey, on cucumber plants grown on a vermiculite base to which nutrient solutions were added. The minor element concentrations were not varied. Nutrients supplied were measured. Statistically the experiment was set up as a 3 × 3 × 3 factorial confounded in blocks of 9 units; the second order interaction being partially confounded. There were 4 replications, each having 27 treatment combinations. No foliage analysis was carried out.

Populations of the mite were doubled when the concentration of the nitrogen was doubled. Higher rates of nitrogen and potassium had a highly significant effect in increasing the fecundity of the mite.

Significant population increases were also ascribed to interactions between increased nitrogen and potassium dosages and nitrogen and phosphorus dosages.

INTRODUCTION

The two-spotted spider mite, *Tetranychus bimaculatus* Harvey, has long been a major pest of cucumbers in greenhouses. A controlled nutritional experiment was undertaken at the Harrow laboratory to ascertain the effects of various levels of nitrogen, phosphorus, and potassium, supplied to the cucumber plant, on the fecundity of this pest. This was done with a view to facilitating its control through manipulation of the fertilizer program.

Rodriguez (15) has adequately, though briefly, summarized the related work of other investigators on the effects of plant food levels in the soil on the growth and reproduction of insects. A number of references given by Painter (14) in his recent book and papers of Auclair and Maltais (2) and Maltais (13) indicate that insect feeding and reproduction are greatly affected by the chemical composition of the plant sap, which in turn is affected by plant nutrition.

Specific work on the effects of plant nutrients or the composition of the plant sap on spider mites is scarce. Whitcomb (20) found that the common red spider, *Tetranychus telarius* (L.), was less abundant on leaves of roses with a high pH. The citrus red mite, *Paratetranychus citri* (McG.), was thought by Thompson (19) to be increased in numbers by the nutritional effects of sprays of copper, and Holloway *et al.* (9) observed a similar result from sprays of copper-, zinc-, and manganese-sulphate. Rodriguez and

[1] Contribution No. 3104, Division of Entomology, Science Service, Department of Agriculture, Ottawa, Canada; from a thesis submitted to McGill University in partial fulfilment of the requirements for the degree of Master of Science, May, 1952.

[2] Assistant Entomologist, now at Science Service Laboratory, St. Jean, Que.

Neiswander (16) reported an apparent decrease in populations of *T. bimaculatus* on greenhouse tomatoes, over a 3-year period in Ohio, with a reduced fertilizer program. Garman and Kennedy (8) found that this mite increased more rapidly on highly fertilized beans and peaches. Rodriguez' (15) most recent studies on the two-spotted spider mite populations on tomato plants in nutrient culture are compared with the writer's results under "Discussion and Conclusions".

MATERIALS AND METHODS

Burpee hybrid cucumber plants were used throughout. Three seeds were planted per pot; and at the cotyledon stage, approximately one week after planting, plants of uniform size were retained, one per pot, and all the others were discarded.

Clay pots, 6 inches in diameter with half-inch drainage holes, afforded sufficient space for the extensive root system developed by the cucumber plants.

All pots were filled with vermiculite. A spectrographic analysis of similar material by C. G. Woodbridge, Division of Chemistry, Canada Department of Agriculture, Summerland, B.C., showed the presence of silicon, iron, calcium, manganese, potassium, and sodium. None of these elements was present in soluble amounts sufficient to become a factor in an experiment of this nature.

Seven concentrated solutions of nutrients labelled A, B, C, D, E, F, and G were prepared as recommended by Hoagland and Arnon (12). The first five of these were molar solutions of $NH_4H_2PO_4$ (the phosphorus source), KNO_3 (the potassium source), $Ca(NO_3)^2$ (the main source of nitrogen), $MgSO_4$, and $CaCl_2$. Stock solution F contained the necessary minor elements (boron, 0.5 p.p.m.; manganese, 0.5 p.p.m.; copper, 0.02 p.p.m.; molybdenum, 0.01 p.p.m.). Stock solution G was the source of iron and was prepared as a 0.5 per cent weight/volume solution of iron tartrate. A standard dilute solution (henceforth called "mixture" to distinguish it from "stock") containing 210.120 milligrams of nitrogen, 31.020 milligrams of phosphorus, and 234.60 milligrams of potassium per litre was prepared from one millilitre of stock A, 6 millilitres of B, 4 millilitres of C, 2 millilitres of D, $7\frac{1}{2}$ millilitres of E, one millilitre of F, and one millilitre of G made up to a volume of one litre. This was the mixture employed to supply the lowest level of all elements to the plant.

The mixture containing the second level of any element was prepared similarly by adding the different stocks in amounts as above, except that sufficient of the stock source of the element to be increased was used to give in the final litre of the mixture one and one-half times as many milligrams of that element as were in the lowest level mixture. The mixture containing the third level of any element contained twice as many milligrams of that element as were in the lowest level mixture.

At the beginning of the experiment, 4 litres of each mixture were prepared and the pH was adjusted to 6 by the method of Spurway (18). These mixtures were stored in a darkened cabinet when not in use.

Sufficient nutrient mixture was added to each pot weekly to maintain growth conditions. Plants were watered daily with distilled water. Loss by drainage was avoided at all times.

Specimens of the spider mite used as the test animal were identified by H. H. J. Nesbitt, Associate Professor of Biology, Carleton College, Ottawa, as of *Tetranychus bimaculatus* Harvey.

One quiescent deutonymph female and three adult males were placed on each plant at the first-leaf stage, that is, approximately one week after the cotyledon stage. These were obtained from an inbred stock that had been isolated for three months before its use. All females were fertilized, as was indicated by the presence of both sexes in the progeny on each plant. No plant or female mite was lost.

Cellulose adhesive tape, one inch wide, was applied around the outside of each pot at the top, and a half-inch barrier of white petroleum jelly was applied to the centre of the tape to prevent foreign mites from gaining access to the host plant, and to prevent the movement of the test animals from plant to plant.

The experiment was set up as a $3 \times 3 \times 3$ factorial confounded in blocks of 9 units. The second order interaction (NPK) was partially confounded in such a way that a different set of each of the two degrees of freedom was used in each of the four replicates [(Cochran and Cox (3)]. Each replicate had 27 treatments, comprising all possible combinations of the three levels of nitrogen, phosphorus, and potassium. There were four replications. Replicates were started at weekly intervals 7 weeks later.

The number of mites and eggs found on treated plants 35 days after each was infested were recorded.

An analysis of variance was carried out on the original total counts as outlined by Cochran and Cox (3). Examination of the data indicates no evident proportionality between treatment means and variance between observed counts so that this procedure followed by use of F-ratio tests would seem justified even though some treatment means differ from others by a factor of two.

RESULTS

Within each replicate there was little variation in growth of the plants until after the third addition of the nutrient solutions. Then the plants fed higher levels of nitrogen were taller and greener and had more leaves regardless of the levels of phosphorus and potassium supplied.

Counts of total mites and eggs (Table 1) showed that nitrogen and potassium had a highly significant effect, and phosphorus a significant effect, on the fecundity of the two-spotted spider mite. The effect of phosphorus reached its maximum at the second level (P_2); no significant change occurring when it was raised to the third level (P_3). It will be noted, however, that with certain combinations such as N_1K_1 and N_3K_1, the effect of phosphorus was to significantly reduce the population at the P_2 level, while it rose again at the P_3 level. Increasing nitrogen and potassium together produced a significant rise in fecundity above that accountable to the nitrogen or potassium alone.

TABLE 1.—TOTALS OF *T. bimaculatus* (EGGS, NYMPHS, ADULTS) ON CUCUMBER PLANTS (4 REPLICATIONS) GROWN ON DIFFERENT LEVELS OF NITROGEN (N), PHOSPHORUS (P), AND POTASSIUM (K) FIVE WEEKS AFTER INFESTATION WITH ONE FEMALE DEUTONYMPH

$N_1P_1K_1$	3984	$N_2P_1K_1$	5117	$N_3P_1K_1$	6487	(P_1K_1)	*5196*
$N_1P_1K_2$	3519	$N_2P_1K_2$	4697	$N_3P_1K_2$	6483	(P_1K_2)	*4566*
$N_1P_1K_3$	3460	$N_2P_1K_3$	4827	$N_3P_1K_3$	7109	(P_1K_3)	*5132*
(N_1P_1)	*3654*	(N_2P_1)	*4880*	(N_3P_1)	*6693*	(P_1)	*5076*
$N_1P_2K_1$	3193	$N_2P_2K_1$	5317	$N_3P_2K_1$	6060	(P_2K_1)	*4857*
$N_1P_2K_2$	3545	$N_2P_2K_2$	5356	$N_3P_2K_2$	6981	(P_2K_2)	*5294*
$N_1P_2K_3$	4032	$N_2P_2K_3$	5037	$N_3P_2K_3$	6856	(P_2K_3)	*5308*
(N_1P_3)	*3590*	(N_2P_2)	*5237*	(N_3P_2)	*6632*	(P_2)	*5153*
$N_1P_3K_1$	3438	$N_2P_3K_1$	4591	$N_3P_3K_1$	6906	(P_3K_1)	*4978*
$N_1P_3K_2$	4161	$N_2P_3K_2$	5192	$N_3P_3K_2$	6187	(P_3K_2)	*5180*
$N_1P_3K_3$	3715	$N_2P_3K_3$	5496	$N_3P_3K_3$	6889	(P_3K_3)	*5367*
(N_1P_3)	*3771*	(N_2P_3)	*5093*	(N_3P_3)	*6661*	(P_3)	*5175*
(N_1)	*3672*	(N_2)	*5070*	(N_3)	*6662*	(Exp.)	*5135*
(N_1K_1)	*3538*	(N_1K_2)	*3742*	(N_1K_3)	*3736*		
(N_2K_1)	*5008*	(N_2K_2)	*5082*	(N_2K_3)	*5120*		
(N_3K_1)	*6448*	(N_3K_2)	*6550*	(N_3K_3)	*6951*		
(K_1)	*5010*	(K_2)	*5125*	(K_3)	*5269*		

Notes:

1. N_1 = lowest level of nitrogen; $N_2 = 1.5 \times N_1$; $N_3 = 2 \times N_2$; similarly P_1, P_2, P_3, and K_1, K_2, K_3 represent levels of P and K used.
2. All totals corrected for block effect.
3. Italics indicate means for levels of individual elements, e.g., N_1 or element pairs e.g. N_1K_1 combined with all levels of the other element.
4. Differences required for significance:

	5 per cent level	1 per cent level
(*a*) Between totals	240	319
(*b*) Between means for combination of two elements	138	184
(*c*) Between means for single elements	80	106

When the interaction variances were further analysed to separate the linear relationships from the quadratic relationships (3, 31), it was found that increasing nitrogen and potassium together, and phosphorus and potassium together, resulted in marked increases in fecundity. The increases were not significant when nitrogen and phosphorus, or nitrogen, phosphorus and potassium, were increased together. There were significant differences in totals for replicates. The total for replicate I was the lowest.

DISCUSSION AND CONCLUSIONS

The results indicate conclusively that high nitrogen and potassium levels were positively correlated with increased fecundity of *T. bimaculatus* on cucumber under conditions of the experiment. This is in agreement with Davidson (7), Dahms *et al.* (5), Dahms and Fenton (6), Dahms (4), and Maltais (13), but contrary to Halloway *et al.* (9), Haseman (10), Arant and Jones (1), and Rodriguez (15).

Nitrogen and potassium together and nitrogen and phosphorus together had significant effects. Phosphorus alone produced an increased fecundity at the second level (P_2), yet in certain combinations such as those with N_1K_1 and N_3K_1 phosphorus at the second level reduced fecundity.

TABLE 2.—ANALYSIS OF VARIANCE BROKEN DOWN TO SHOW THE LINEAR AND QUADRATIC COMPONENTS OF THE MAIN TREATMENT EFFECTS AND THEIR INTERACTIONS

Treatment combination	Linear and quadratic components	Degrees of freedom	Mean square[1]	F	F	
					5 per cent level	1 per cent level
N	L	1	10058360.1039**	5563.7	4	7.08
	Q	1	7740.0416*	4.3	4	7.08
P	L	1	6160.5000	3.4	4	7.08
	Q	1	337.5000	—	—	—
K	L	1	75272.0000*	41.6	4	7.08
	Q	1	150.0000	—	—	—
NP	LXL	1	4181.3333	2.3	4	7.08
	Rest	3	10998.3704	6.1	2.76	4.13
NK	LXL	1	13635.0208**	7.5	4	7.08
	Rest	3	11939.7523	6.6	2.76	4.13
PK	LXL	1	38363.5208**	21.2	4	7.08
	Rest	3	20351.7708	1.1	2.76	4.13
NPK	LXLXL	1	2210.5601	1.2	4	7.08

[1] Tests of significance in this table are to be made against the original error variance i.e., M.S., for error, 1807.8405.

* Significant at the 5 per cent level.

** Significant at the 1 per cent level.

This serves to emphasize the importance of the level of one chemical on the absorption of another. No check was possible in this work as no leaf analyses were made. There is some doubt too as to the value of leaf analyses because of the variation in amounts present in the same foliage at different times even during the same day. Rodriguez (15), doing a similar study using tomato as his host plant, carried out leaf analyses. He found three times as many mites in foliage low in nitrogen as in that high in nitrogen. Nitrogen absorption was positively correlated with nitrogen supplied. The amount of potassium supplied but not that absorbed was positively correlated with the mite population.

Rodriguez used groups of five female mites without any certainty that they had been fertilized and confined his populations to one leaflet for 30 days. The writer used individual fertilized females and allowed the progeny to seek the part of the plant which they preferred. The small size of Rodriguez' populations (15, 7) may have been partly a result of close confinement and of host resistance, or more likely a result of his not including eggs in the counts. He does not say whether or not he controlled the pH of his solutions.

The smaller total populations obtained by the writer in replicate I would seem to be due to a lower fecundity of the mites used. This can only be ascribed to the fact that the deutonymphs used belonged to a population which had not been reared on cucumber for as long as those populations which supplied deutonymphs for the later replications. The test animals were originally taken from clover and transferred to cucumber. It seems possible that over several generations there may have been selected a strain better adapted to cucumber.

It is evident from the population totals of all treatments (Table 1) that the mites would have reached high infestation levels had the experiment been continued and that none of the nutrient levels used would have given enconomic control of this pest. However, the total population on all plants receiving the lowest level of nitrogen was approximately half that on plants fed the highest amounts of nitrogen. These data suggest that a carefully proportioned fertilizing program might result in lower infestations of the two-spotted spider mite on hothouse cucumber. Such infestations might then be more effectively controlled with modern acaricides.

It is not known whether the level of the nutrients can be adjusted to produce good yields of edible fruit and at the same time reduce mite fecundity sufficiently to render the pest unimportant.

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THE INHERITANCE OF RACHIS STRENGTH IN BARLEY[1]

M. L. Kaufmann[2] and L. H. Shebeski[3]

University of Saskatchewan, Saskatoon, Sask.

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ABSTRACT

The inheritance of rachis strength was studied in four barley crosses, two in the F_2 and two in the F_3. The results obtained gave strong evidence that resistance to rachis break is due to a single recessive gene. A preliminary study indicated that there was no difference in threshability of the tough and weak rachis segregates from the crosses.

INTRODUCTION

All of the varieties of barley licensed for sale in Canada that are eligible for the No. 1 C.W. and No. 2 C.W. Six-Row grades, and many of the feed varieties as well, are subject to partial or complete head loss due to rachis break on reaching maturity. This has been well established at Saskatoon where notes have been taken on head loss after maturity for many years. Varieties such as O.A.C. 21 and Montcalm in several of the years have lost at least 90 per cent of their heads through rachis break one to three weeks after maturity, whereas varieties such as Beecher and Gem showed no head loss in the same tests.

Weak rachis should not be mistaken for brittle rachis as found in *Hordeum spontaneum* C. Koch and *Hordeum agriocrithon* E. Aberg. There are a number of reports concerning the relatively simple dominant inheritance of brittle rachis and these have been received by Smith (3). However, the authors were unable to find published reports on the inheritance of a weak rachis. Aberg and Wiebe (1) indicate that there are variations in degree of toughness within the tough rachis group and that the variation seems to be due to both genetic and environmental factors.

Beck (2) crossed two tough rachis varieties (Beecher and Gem) with a weak rachis variety (O.A.C. 21) and obtained a 3 : 1 ratio in the F_2 of both crosses with tough rachis being dominant.

MATERIALS AND METHODS

Two sets of crosses were studied. The first set, studied in F_3, consisted of O.A.C. 21 × Gem and O.A.C. 21 × Beecher. Plants classified as homozygous resistant to rachis break were selected from each of the two crosses and their progeny were used in the second set of crosses which were (O.A.C. 21 × Gem) × U.M. 1020 and (O.A.C. 21 × Beecher) × U.M. 1020. These were studied in the F_2.

Gem and Beecher have a strong rachis; O.A.C. 21 and U.M. 1020 have a weak rachis. Gem and Beecher, however, are both poor in malting quality and low in yield when grown in Central and Northern Saskatchewan. O.A.C. 21 and U.M. 1020 are both rated high in malting quality and are also fairly high in yield. These two varieties are similar in other respects excepting that U.M. 1020 is resistant to stem rust.

[1] Contribution from the Department of Field Husbandry, University of Saskatchewan.
[2] Graduate Assistant in Cereal Breeding.
[3] Associate Professor of Field Husbandry.

FIGURE 1. A comparison of O.A.C. 21 (*left*) with O.A.C. 21 × Beecher. The latter had withstood considerable abuse before the photograph was taken.

The progeny of each of the F_2 plants of the crosses O.A.C. 21 × Gem and O.A.C. 21 × Beecher studied by Beck (2) were grown during the summer of 1951 in rows 11.5 feet long, spaced one foot apart. Checks were planted at ten row intervals and alternated in the order O.A.C. 21, Gem, O.A.C. 21, Beecher. The F_3 rows were classified as strong rachis, segregating and weak rachis. This was done in the field after the O.A.C. 21 check rows had suffered severe damage from rachis break. At that time the Gem check rows which had matured about the same time as O.A.C. 21, and the Beecher rows which had matured earlier, showed no signs of rachis break.

One F_3 plant from the O.A.C. 21 × Gem cross and two F_3 plants from the O.A.C. 21 × Beecher cross were selected as strong rachis parents for the second set of crosses. The crosses between the progeny of these selections and U.M. 1020 were made in the greenhouse in the fall of 1951. The F_1 populations were also grown in the greenhouse, but, since it was necessary to harvest the plants as soon as ripening occurred, the strength of the rachis in the F_1 was not tested.

The parents and the F_2 of both crosses were grown in 1952 under comparable conditions. The F_2 plants were classified in the field at least two weeks after O.A.C. 21 and U.M. 1020 had suffered considerably from rachis break. At that time the resistant checks were undamaged (see Figure 1). Some plants appeared in better condition than those of the two susceptible checks and could have been placed in an intermediate group. However, it was difficult to differentiate between the intermediate and the weak rachis groups so these were combined and the plants were classified as either having a tough or weak rachis.

EXPERIMENTAL RESULTS

Classification of some of the F_3 rows in both crosses was particularly difficult. Because of the high rainfall, considerable lodging had occurred and some of the lodged plants were protected from rachis break. It was often difficult to differentiate between a segregating and homozygous weak rachis row; therefore, these two classes were combined. There was no doubt as to the proper classification of the rows that showed complete resistance to rachis break.

The data on the classification of the F_3 of the O.A.C. 21 × Gem cross are presented in Table 1.

TABLE 1.—CALCULATION OF GOODNESS OF FIT TO A 3 : 1 RATIO FOR THE O.A.C. 21 × GEM CROSS

Phenotype	Observed	Calculated	X^2	Probability range
Wr*	110	100.5	3.59	0.05–0.10
wr	24	33.5		

* Since the character studied has not been symbolized, Wr is used for weak rachis in this paper.

The data on the classification of the F_3 of the O.A.C. 21 × Beecher cross are presented in Table 2.

TABLE 2.—CALCULATION OF GOODNESS OF FIT TO A 3 : 1 RATIO FOR THE O.A.C. 21 × BEECHER CROSS

Phenotype	Observed	Calculated	X^2	Probability range
Wr	106	106.5	0.009	0.90–0.95
wr	36	35.5		

A satisfactory fit to a 3 : 1 ratio was obtained in both crosses, which is a good indication that rachis strength is controlled by a single gene with weak rachis being dominant.

The data on the classification of the F_2 of the (O.A.C. 21 × Gem) × U.M. 1020 cross are presented in Table 3.

TABLE 3.—CALCULATION OF GOODNESS OF FIT TO A 3 : 1 RATIO FOR THE (O.A.C. 21 × GEM) × U.M. 1020 CROSS

Phenotype	Observed	Calculated	X^2	Probability range
Wr	379	385.5	0.44	0.50–0.70
wr	135	128.5		

The data on the classification of the F_2 of the (O.A.C. 21 × Beecher) × U.M. 1020 cross are presented in Table 4.

TABLE 4.—CALCULATION OF GOODNESS OF FIT TO A 3 : 1 RATIO OF THE (O.A.C. 21 × BEECHER) × U.M. 1020 CROSS

Phenotype	Observed	Calculated	X^2	Probability range
Wr	541	537	0.12	0.70–0.80
wr	175	179		

An excellent fit to a 3 : 1 ratio was obtained for each of the crosses indicating single gene inheritance. Weak rachis was considered dominant.

DISCUSSION

On the basis of the very satisfactory fits to a 3 : 1 ratio in each of the four crosses studied, resistance to rachis break after maturity in cultivated barleys may be considered to be recessive and simply inherited.

The results obtained are not in agreement with those obtained by Beck (2) since he obtained a 3 : 1 ratio in the F_2 with tough rachis being dominant. However, many of the plants he had classified as having a tough rachis produced progeny with a weak rachis. This would indicate that his method of classification was inadequate to differentiate between the weak and tough rachis groups.

Findings concerning simple inheritance of rachis strength should have an effect on the future methods of barley breeding. Emphasis, in recent years, has been placed on breeding for stronger straw and more erect heads in order to obtain barley varieties more suitable for combine harvesting. Varieties of this type will be more subject to rachis break because the heads will be exposed to weather to a greater degree than for varieties with weaker straw and nodding heads. Therefore, it should be necessary to breed for tough rachis.

There is sufficient evidence of simple inheritance for tough rachis so that the backcross method of plant breeding can be used to reconstitute a weak rachis variety with a tough rachis.

A problem that may accompany the transmission of a tough rachis is also the transmission of difficulty in threshing. This problem was studied in a preliminary way using F_4 lines and F_2 plants. It was noted that no greater difficulty was experienced in threshing the tough rachis lines and plants than was experienced with the weak rachis ones.

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EXPERIMENTS OF THE INSECTICIDAL CONTROL OF THE TUBER FLEA BEETLE, *EPITRIX TUBERIS* GENT., IN THE INTERIOR OF BRITISH COLUMBIA[1]

D. G. FINLAYSON[2] AND C. L. NEILSON[3]

Field Crop Insect Section, Laboratory of Entomology, Kamloops, B.C.

[Received for publication June 10, 1953]

ABSTRACT

Experiments on insecticidal control of the tuber flea beetle, *Epitrix tuberis* Gent., were conducted in 1947, 1948, and 1949 in the interior of British Columbia, where 2 generations of the beetle occur annually. Five dusts, DDT, chlordane, toxaphene, parathion, and DDT-cryolite, were applied to the potato foliage at various rates and concentrations. The first three gave effective commercial control when applied at approximately 10-day intervals throughout the growing season, 6 applications of 5 per cent DDT, at 20 pounds per acre for the first two and 30 pounds for the remainder, being the most economical. Harvesting the main crop before mid-September avoids most of the damage inflicted by second-generation larvae.

INTRODUCTION

The tuber flea beetle, *Epitrix tuberis* Gent., has been a pest of potatoes in British Columbia since 1940, but in the interior areas of the province only since 1944 (2). Experiments on control with DDT and DDT-cryolite were initiated in 1947 following infestation surveys made during 1945 and 1946. The first year's experiments were exploratory; however, results at 4 sites were consistent. The scope of the investigation was widened in 1948 and 1949 to include chlordane, toxaphene, and parathion, and the results are presented below.

MATERIALS AND METHODS

In 1948 and 1949 each treatment was replicated 4 times and the plots were arranged in randomized blocks. The plots were of approximately one-twentieth of an acre in 1948 and one-fortieth of an acre in 1949.

The insecticides used were: DDT, DDT-cryolite, toxaphene, chlordane, and parathion. All were commercially prepared and applied as dusts between 4 and 8 a.m., when dew was still on the foliage and winds were minimal. The dusts were applied by means of a Niagara rotary hand duster. The initial application was made when approximately 75 per cent of the plants were about 2 inches above the ground, the remainder at 10- to 20-day intervals dependent on populations. The rates and dates of applications are shown in Table 1.

The adult population was estimated by making a number of collections per plot, each collection consisting of the insects taken in 10 sweeps with a 14-inch net and each sweep contacting 3 or 4 plants. These collections were made within 24 hours before dust application. At Merritt in 1948 similar collections were also made 48 hours after treatment. The collections were made at Merritt by the senior author and at Rayleigh and Westsyde by the junior author.

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[1] Contribution No. 3099, Division of Entomology, Science Service, Department of Agriculture, Ottawa Canada.

[2] Assistant Entomologist.

[3] Associate Entomologist; Provincial Entomologist, Department of Agriculture, Vernon, B.C., since November, 1950.

TABLE 1.—RATES AND DATES OF APPLICATIONS OF DUSTS AGAINST THE TUBER FLEA BEETLE IN THE INTERIOR OF BRITISH COLUMBIA, 1948 AND 1949

Treatment	Pounds of toxicant per acre per application						Total toxicant, lb.
	Date of application at Rayleigh A 1948**						
	June 24	July 14	July 20	July 29	Aug. 12	Aug. 24	
3% DDT	0.6	0.6	0.9	0.9	0.9	0.9	4.8
5% DDT	1.0	1.0	1.5	1.5	1.5	1.5	8.0
DDT-cryolite*	5.5	5.5	8.25	8.25	8.25	8.25	44.0
5% chlordane	1.0	1.0	1.5	1.5	1.5	1.5	8.0
Untreated	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Date of application at Merritt 1948						
	June 10	June 20	July 3	July 20	Aug. 10	Sept. 1	
3% DDT	0.6	0.6	0.9	0.9	0.9	0.9	4.8
5% DDT	1.0	1.0	1.5	1.5	1.5	1.5	8.0
DDT-cryolite*	5.5	5.5	8.25	8.25	8.25	8.25	44.0
10% toxaphene	2.0	2.0	3.0	3.0	3.0	3.0	16.0
5% chlordane	1.0	1.0	1.5	1.5	1.5	1.5	8.0
Untreated	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Date of application at Westsyde 1949						
	June 5	June 14	June 29	July 22	Aug. 5		
3% DDT	0.6	0.6	0.9	0.9	0.9	—	3.9
5% DDT	1.0	1.0	1.5	1.5	1.5	—	6.5
10% toxaphene	2.0	2.0	3.0	3.0	3.0	—	13.0
1% parathion	0.2	0.2	0.3	0.3	0.3	—	1.3
Untreated	0.0	0.0	0.0	0.0	0.0	—	0.0
5% DDT	1.0	1.5	2.0	1.5	1.5	—	7.5
2% parathion	0.4	0.4	0.6	0.6	0.6	—	2.6

* DDT-cryolite (sodium fluoaluminate): 5 lb. of 50 per cent DDT, 25 lb. of cryolite, 70 lb. of talc.
** A second site, Rayleigh B, received the first, third, fourth, and fifth applications only.

Larval and pupal populations were estimated at Merritt in 1948 by flotation of soil samples taken within 48 hours after each of the second to sixth dust applications. A sample consisted of 4 hills, 1 from each replicate for each treatment on each of 5 dates at approximately 10-day intervals from June 26 to August 23. Each hill dug consisted of the soil from an area 12 inches square and 8 inches deep, with the potato stem at the centre. The soil mass was halved, and each portion was put into a pail of water and mixed thoroughly. The liquid was decanted through a modification of the apparatus used by Shirck (3) and Daniels (1), with 3 trays instead of 4. The trays were made of copper screening, the top tray of 10-mesh and the bottom two of 20-mesh. The screens were washed with clean water to remove excess soil and all larvae and pupae obtained were counted.

TABLE 2.—REDUCTIONS IN NUMBERS OF ADULTS OF THE TUBER FLEA BEETLE AFTER APPLICATIONS OF VARIOUS DUSTS, MERRITT, B.C., 1948

Treatment*	Average number per collection per plot (3 collections of 10 sweeps each in each of 4 replicates)											
	Date of application											
	June 10		June 20		July 3		July 20		Aug. 10		Sept. 1	
	B**	A	B	A	B	A	B	A	B	A	B	A
3% DDT	2	1	7	0	4	0	4	0	9	2	9	0
5% DDT	1	0	5	0	2	0	3	0	8	1	6	0
DDT-cryolite	1	0	3	0	2	0	7	0	11	2	10	0
10% toxaphene	1	1	5	0	2	0	9	0	18	2	18	0
5% chlordane	1	0	5	0	5	0	4	0	9	1	9	0
Untreated	1	—	9	—	3	—	21	—	84	—	65	—

* For rates of application see Table 1.
** B and A represent collections made within 24 hours before and 48 hours after applications of insecticides.

TABLE 3.—PERCENTAGES OF COMMERCIAL TUBERS OBTAINED AFTER DUSTING FOR CONTROL OF THE TUBER FLEA BEETLE AT WESTSYDE, RAYLEIGH, AND MERRITT, B.C., 1948 AND 1949

Treatment*	1948			1949
	Rayleigh		Merritt	Westsyde
	Site A Sept. 21	Site B Aug. 31	Sept. 11	Aug. 25
3% DDT	75.8	100	84.3	92.0
5% DDT	84.8	100	80.2	97.6
DDT-cryolite	75.6	97.7	65.0	—
10% toxaphene	—	—	94.8	98.4
5% chlordane	86.0	100	88.8	—
Untreated	46.1	100	59.6	77.8
5% DDT	—	—	—	90.7
1% parathion	—	—	—	93.6
2% parathion	—	—	—	95·3
Difference necessary for significance at 1% level	22.6	N.s.d.	N.s.d.	N.s.d.

* See Table 1 for rates of application.

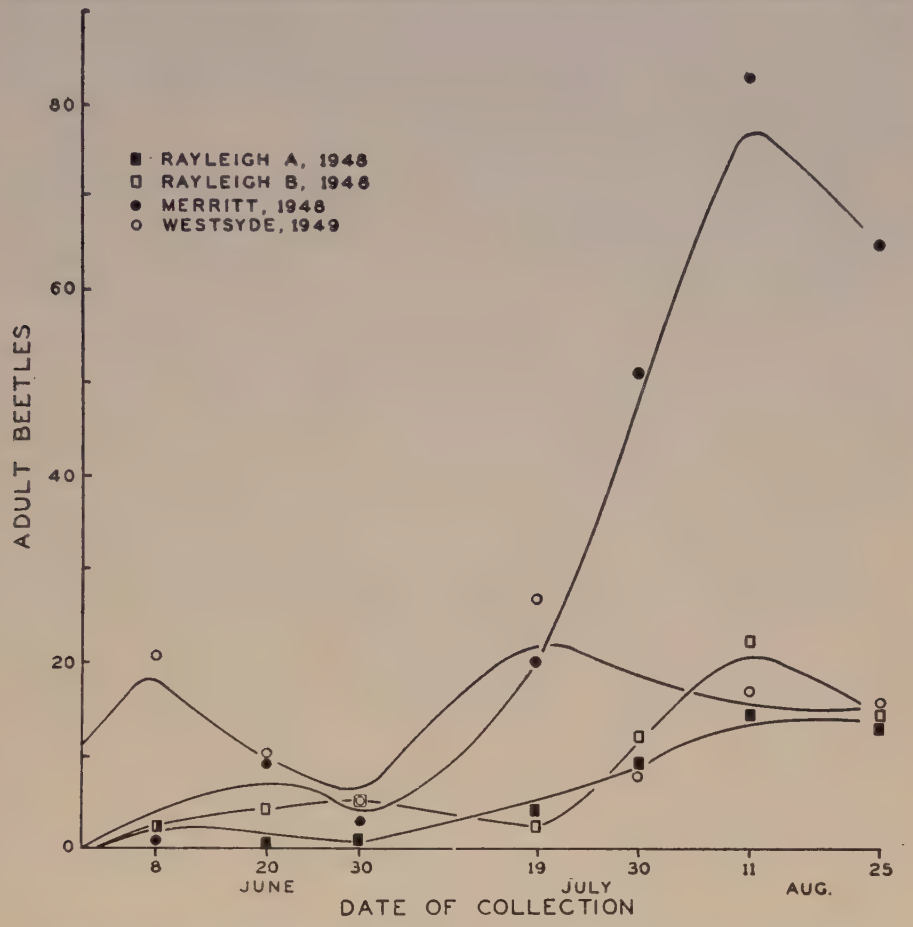

FIGURE 1. Average numbers of adults of the tuber flea beetle per collection per plot (3 collections of 10 sweeps each in each of 4 replicates) at Merritt and Rayleigh, 1948, and Westsyde, B.C., 1949.

To appraise larval damage, samples of tubers from all treatments were examined as follows: Rayleigh, 1948, site B, August 31; Merritt, 1948, September 11; and Westsyde, 1949, August 25, all before the peak populations of second-generation larvae; and Rayleigh, 1948, site A, September 21, after the peak population of second-generation larvae. The tubers were peeled with a hand potato peeler and the individual larval tunnels were counted. Since the commercial grades vary with the supply and demand of potatoes, an arbitrary limit of not more than 5 blemishes per tuber was selected as the criterion of marketable tubers.

The efficiency of the treatments was measured in 3 ways: (*a*) cost, (*b*) reduction in populations, and (*c*) percentage of marketable tubers. The variety of potato used was Netted Gem.

RESULTS AND DISCUSSION

The population counts in 1948 and 1949 showed that 2 generations of the beetle occur each year. The overwintering adults were found in the

potato fields from the last week of May to the second week of June; the first-generation adults emerged from July 1 to July 20 (Figure 1). The second-generation adults began emerging about September 1, going into hibernation almost with the first degree of frost.

Table 2 shows the reductions in numbers of adults after applications of the dusts at Merritt in 1948. Each of the insecticides reduced the population effectively. The counts before the applications at sites A and B at Rayleigh in 1948 showed similar reductions. However, the emergence of adults over long periods necessitates repeated applications, for additional foliage growth permits the beetles to survive on untreated foliage.

Although the sample was small, Chi-squared analysis showed that the reductions in numbers of larvae and pupae obtained by the dusting were highly significant. The average number of larvae per hill in treated plots for all sampling dates ranged from 1.0 (5 per cent DDT) to 1.5 (DDT-cryolite); that of pupae, from 2.3 (3 per cent DDT) to 3.2 (10 per cent toxaphene). The averages for the untreated plots were 5.4 larvae and 15.0 pupae.

Damage to tubers taken on August 31, 1948, at Rayleigh was not significantly less for the treated plots, or for those taken at Merritt on September 11. However, the damage in samples taken at Rayleigh on September 21, when the second-generation larvae had inflicted severe damage in the check plots, was significantly less at the 1 per cent level for the treated plots (Table 3). This showed the danger of leaving tubers in the ground after the second week of September. The sample taken in 1949 in late August supported the conclusion that early digging helps to avoid the severe damage inflicted by the second generation.

The amounts of chlordane and toxaphene used cost more than that of 5 per cent DDT. The 3 years' investigations indicate that, although chlordane and toxaphene are each highly efficient, the cheapest and longest protection is afforded by the application of 5 per cent DDT dust.

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DISTRIBUTION OF THE UNDERGROUND PARTS OF LEAFY SPURGE (*EUPHORBIA ESULA* L.)[1]

ROBERT T. COUPLAND AND JACK F. ALEX[2]

Department of Plant Ecology, University of Saskatchewan, Saskatoon, Sask.

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ABSTRACT

Detailed data are presented concerning the distribution of the underground plant parts of leafy spurge as a result of excavations in 32 sites throughout southern Saskatchewan. The amount of oven-dry plant material of this weed averaged 22.11 ± 2.00 gm. per cu. ft. to a depth of 48 in. (8,492 pounds per acre), 56 per cent of this occurring in the uppermost 6-inch layer of soil. The total weight and the proportion in the uppermost 6-inch layer was greatest in areas of invaded native grassland and lowest in cultivated land. The weight of plant material of the weed in every layer of soil was highest in native grassland. Negative correlation could not be shown between the total weight of plant material of the weed and that of competing species below patches of leafy spurge. The effect of soil texture on total weight of plant material of the weed in the soil was found to be small but the distribution according to depth was affected. The density of plant material in each major soil horizon is also discussed as affected by land use and soil texture. Data are presented to illustrate the distribution of plant parts of various sizes in each layer of soil. The maximum depth of penetration of leafy spurge was found to be 98 in. In all instances except one the roots extended deeper than 48 in. in the soil. These findings are discussed in relation to control of the species.

INTRODUCTION

Leafy spurge (*Euphorbia esula* L.) is one of several exotic persistent perennial weeds which are increasing in abundance and frequency in North America. This species was introduced to this continent from Eurasia prior to 1827 and has slowly but steadily spread so that it has now been found in nearly every province in Canada and most of the states in the northern half of the United States (4, 5). The first reported collection in Canada was from Ontario in 1889 (3).

The difficulty of controlling leafy spurge is indicated by reports that at least two years of intensive cultivation or the use of soil sterilants is required to effect eradication. Both measures are expensive and difficult to apply effectively (5, 6, 10, 11). Competition provided by seeding infestations with perennial forage grasses has reduced the density of shoots of the weed but has not resulted in death of the roots (8, 11).

That the methods of control at present being employed are ineffective under most conditions is indicated from the results of a survey conducted in Saskatchewan by Coupland and his associates[3]. During 1949 to 1952 infestations of leafy spurge were mapped in 7,950 acres in 517 quarter sections in 55 of the 73 municipalities surveyed. The area surveyed is about one-fifth of the settled portion of the province. The habitats involved varied from land which was being cropped to that which was occupied by undisturbed native plant communities. A wide range of soils was infested, varying in texture from heavy clay to sand.

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[2] Associate Professor and formerly Graduate Assistant in Plant Ecology, respectively.

[3] Coupland, R. T., *et al.* Survey of the abundance and distribution of persistent perennial weeds in Saskatchewan. Dept. of Plant Ecology, Univ. of Sask. *Typewritten annual reports.* 1950-53.

Relatively few studies have been made of the life history of leafy spurge. The purposes of the present investigation were to study the distribution of the root system and underground stems of this species under a variety of environmental conditions in infestations which have become established throughout Saskatchewan and to relate this to control.

Many of the characteristics of the underground parts of leafy spurge are similar to those of toadflax (*Linaria vulgaris* Hill), as observed by the present authors, and to those of Russian knapweed (*Centaurea repens* L.), hoary cresses (*Cardaria* spp.) and field bindweed (*Convolvulus arvensis* L.) which have been described by Frazier (2). These characteristics are associated with a very vigorous habit of growth. Kirk *et al.*[1] observed that one seedling of leafy spurge increased in size to occupy an area of soil 24 ft. in diameter in four years. Even greater rates of spread were recorded for plants established by planting pieces of roots[2]. Vertical tap roots branch and rebranch profusely to produce numerous coarse and fine roots. Near the surface a network of horizontal branches give rise to many leafy shoots[2] (5). The roots have been observed to penetrate deeply, one investigator finding one reaching to a depth of 15.7 ft. below the surface (1). Hanson and Rudd (5) reported that the stem of leafy spurge may extend underground to a depth of one foot or more before the region of transition from stem to root is reached. Horizontal structures transitional between stem and root were found by these authors to arise from vertical underground stems and from the main roots as deeply as 20 in. below the soil surface. Eventually these horizontal structures turn downward to become vertical tap roots for shoots which originate near the bend[2]. The roots have been reported to change in colour from brownish to yellowish to whitish with increasing depth (5).

The persistence of the underground parts and their resistance to eradication by control measures have been accounted for by the presence of a thick, corky covering which is resistant to decay (7), by the presence of reproductive buds on the rhizomes and roots to a considerable depth in the soil, and by the extensive root system (5).

The distribution of reproductive buds on the roots has been discussed (5). A later paper by the present authors will be concerned with this subject.

METHODS AND PROCEDURE

In order to obtain a measure of root development in a variety of habitats samples were obtained under eight conditions of land use, ranging from cultivated soil to native grassland, and in soil types ranging from dune sand to heavy clay. A total of 44 excavations were dug in 32 sites which were chosen for study in 11 soil associations throughout the brown, dark-brown, black and black-grey soil zones of Saskatchewan. The area sampled is 325 miles across.

The monolith method of Weaver and Darland (9) was used to remove 44 blocks of soil containing underground parts of leafy spurge from 39 of

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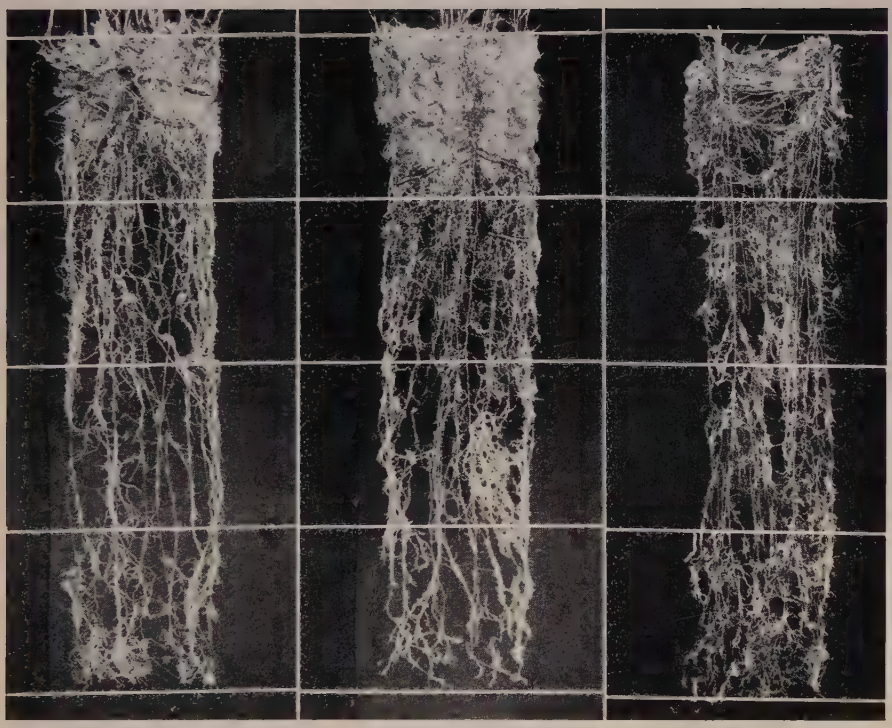

FIGURE 1. Underground plant parts of leafy spurge which were present in three monoliths (3 × 12 in. in cross section and 48 in. in depth). The horizontal white lines represent intervals of one foot. **A.** From a patch in native grassland (leafy spurge 37.03 gm.; competing species 8.82 gm.). **B.** From abandoned land seeded to crested wheat grass (leafy spurge 24.74 gm.; competing species 7.08 gm.). **C.** From cultivated land (leafy spurge 19.48 gm.; competing material 0.36 gm.).

the excavations. This method involves digging a trench 4 ft. long and 2.5 ft. wide to a depth of 5 ft. adjacent to the portion of a patch selected for removal. The face of the soil profile from where the monolith is to be removed is then planed smooth. Soil is next removed to a depth of 4 in. into the face of the profile from each side and from the bottom of the block of soil which is desired. The column of soil that is left is 12 in. wide and extends vertically from the ground surface to a depth of 48 in. A wooden box 3 × 12 × 48 in. inside measurement is then fitted over the column, and braced in position while the monolith is cut away from the side of the excavation. The rough exposed surface is then planed down level with the box so as to obtain a uniform 3-inch thickness of soil in the column. These monoliths were transported to Saskatoon.

Most monoliths were removed in August and September and kept under dry conditions until winter when the soil was washed from the roots. The latter operation was facilitated by preliminary soaking for about 24 hours. Washing was done with the column lying about 15° from the horizontal. The roots were kept in position by use of metal bars laid across the profile, the weight of which forced the roots into the remaining soil as they became exposed by the gentle eroding action of the water spray. In order to facilitate removal of the washed roots from the box, wire screen was placed in the back of the box before it was fitted over the column in the trench. When most of the soil had been washed away the screen supporting the root material was removed and final cleaning was done on it. The root material was then transferred for photographing to a board covered by black felt. The underground parts were then cut into sections according to depth of soil horizons and at arbitrary depths. The underground material of leafy spurge from each level was next divided into five groups on the basis of diameter and the competing plant material was separated from that of leafy spurge. Each subsample was oven-dried and weighed to obtain dry matter content. A soil profile description was made from a smaller monolith (2 × 4 × 36 in.) removed at the time of taking the the large soil column.*

The monolith method was employed in this study to investigate the distribution of the root system of leafy spurge only to a depth of 48 in. In order to obtain further data, particularly at greater depths, roots were traced with an ice pick. This permitted obtaining data on maximum depth of penetration of roots.

EXPERIMENTAL RESULTS

The distribution by weight of underground plant parts of leafy spurge in 6-inch layers to a depth of 48 in. was obtained from 39 excavations. The data were also compiled to measure the density of plant material in each major soil horizon. In addition the plant material in each layer was divided into five classes on the basis of the diameter of cross section of each piece. The underground plant parts include stem tissue, as well as roots. The stems and root-stem transitions comprise a large proportion of the total weight in the uppermost layers of soil. An investigation of the underground distribution of stem tissue is being planned as a future study.

* Personnel of the Saskatchewan Soil Survey made an examination of each soil monolith.

TABLE 1.—MEAN WEIGHT OF OVEN-DRY MATERIAL OF LEAFY SPURGE IN EACH 6-INCH LAYER OF SOIL BELOW 0.25 SQ. FT. OF SURFACE. THE PERCENTAGE OF PLANT MATERIAL IN EACH LAYER AND MEASURES OF VARIABILITY ARE INCLUDED. DATA ARE FROM 39 EXCAVATIONS

	Soil layer (in.)								Total
	0–6	6–12	12–18	18–24	24–30	30–36	36–42	42–48	
Weight (gm.)	12.42	3.71	1.75	1.24	0.98	0.80	0.68	0.53	22.11
Standard error (gm.)	1.29	0.44	0.20	0.14	0.11	0.11	0.10	0.10	2.00
Coefficient of variation (per cent)	62.8	71.7	67.2	70.0	69.8	80.0	85.0	109.8	54.8
Percentage in each layer	56.2	16.8	7.9	5.6	4.4	3.6	3.1	2.4	100.0

TABLE 2.—MEAN WEIGHT OF OVEN-DRY MATERIAL OF LEAFY SPURGE AND COMPETING VEGETATION TO A DEPTH OF 48 IN. BELOW 0.25 SQ. FT. OF SURFACE SOIL UNDER DIFFERENT LAND USE. MEASURES OF VARIABILITY ARE ALSO INCLUDED

Land use	Number of excavations	Leafy spurge			Competing vegetation	
		Mean weight (gm.)	Range (gm.)	S. E. (gm.)	Mean weight (gm.)	Range (gm.)
Native vegetation—	10	28.35	—	3.82	30.02	—
Grassland	5	39.91	30.36–46.75	2.89	10.30	3.60–17.32
Meadow	2	16.75	16.46–17.05	0.36	52.41	42.02–62.80
Trees and shrub	3	16.81	1.62–44.41	13.82	47.94	36.98–68.65
Abandoned from cultivation—	16	21.68	—	2.46	8.61	—
Naturally regrassed	6	24.66	5.15–42.12	1.66	13.07	3.09–26.42
Reseeded to grass	5	23.27	12.51–34.74	3.55	1.82	0.00– 7.08
Perennial weeds	5	16.52	0.98–25.77	4.32	10.05	0.16–25.06
Cultivated	13	17.83	6.32–32.96	2.04	1.59	0.00– 9.22

TABLE 3.—MEAN WEIGHT (GM.) OF OVEN-DRY MATERIAL OF LEAFY SPURGE IN EACH 6-INCH LAYER OF SOIL BELOW 0.25 SQ. FT. OF SURFACE UNDER EACH LAND USE

Land use	Number of excavations	Soil layer (in.)								Total
		0–6	6–12	12–18	18–24	24–30	30–36	36–42	42–48	
Native vegetation—										
Grassland	5	22.55	6.38	3.16	2.18	1.73	1.50	1.34	1.07	39.91
Meadow	2	14.54	0.70	0.31	0.26	0.22	0.26	0.24	0.22	16.75
Trees and shrub	3	10.37	2.30	1.25	1.45	0.61	0.40	0.13	0.30	16.81
Weighted mean	10	17.29	4.02	2.02	1.58	1.09	0.92	0.76	0.67	28.35
Abandoned from cultivation—										
Naturally regrassed	6	15.01	3.08	1.61	1.15	1.22	1.01	0.70	0.88	24.66
Reseeded to grass	5	11.40	4.91	2.30	1.55	1.03	0.86	0.74	0.48	23.27
Perennial weeds	5	10.18	3.07	1.09	0.63	0.41	0.36	0.42	0.36	16.52
Weighted mean	16	12.37	3.65	1.66	1.11	0.91	0.76	0.63	0.59	21.68
Cultivated	13	8.72	3.54	1.66	1.13	0.98	0.76	0.72	0.32	17.83

TABLE 4.—MEAN WEIGHT AND PERCENTAGE OF OVEN-DRY MATERIAL OF LEAFY SPURGE IN EACH 6-INCH LAYER OF SOIL BELOW 0.25 SQ. FT. OF SURFACE IN TEN SOILS OF LOAM TEXTURE AND FINER AS COMPARED WITH 29 SOILS OF COARSER TEXTURE THAN LOAM

	Soil layer (in.)								Total
	0–6	6–12	12–18	18–24	24–30	30–36	36–42	42–48	
Weight (gm.)—									
Soils of fine texture	10.98	4.25	1.89	1.23	0.92	0.61	0.49	0.28	20.65
Soils of coarse texture	12.92	3.52	1.70	1.24	1.00	0.86	0.75	0.62	22.61

Distribution by Weight of Underground Parts

The mean oven-dry weight of underground parts of leafy spurge per cu. ft. to a depth of 48 in. was 22.11 ± 2.00 gm., or the equivalent of 8,492 pounds per acre. The proportion of this weight which was contributed by plant material in the uppermost 6 in. of soil was 56.2 per cent, while that contributed by each layer decreased steadily with depth from 16.8 per cent in the 6- to 12-inch layer to 2.4 per cent in the 42- to 48-inch layer. The variability of the samples was high, the coefficient of variation of the total weights of the samples being 54.8 per cent. This variation increased with depth from 62.8 per cent in the surface layer to 109.8 per cent in the deepest layer (Table 1).

The relation of the quantity of underground plant material to the use of the land in which the weed was growing indicated a significantly higher mean weight ($P = 0.03$) in land which had never been cultivated (28.35 gm.) than in land which had been cultivated within one year of the time of excavation (17.83 gm.) (Table 2 and Figure 1). The yield in areas of land abandoned from cultivation was intermediate (21.68 gm.), but the number of samples was not sufficient to show this to be significantly different from either the unploughed or the cultivated land. The greatest weights of plant parts were found to be in soil occupied by native grassland which had been invaded by the weed. The quantity found indicates that the development of underground parts of leafy spurge is significantly greater in these areas than in any others. However, most of this difference is the result of the quantity of plant material in the uppermost 6-inch layer of soil. The proportion of the weight in the latter layer was highest in uncultivated land (64.2 per cent) and lowest in cultivated land (48.9 per cent), that of the land abandoned for more than one year (57.4 per cent) being intermediate. However, the weights of material in the layers below a depth of 6 in. are more similar under different land uses but are all highest in native grassland (Table 3).

TABLE 5.—MEAN DENSITY (WEIGHT IN GM. PER CU. FT.) OF MATERIAL OF LEAFY SPURGE IN EACH MAJOR SOIL HORIZON TO A DEPTH OF 48 IN. UNDER DIFFERENT CONDITIONS OF LAND USE

Land use	Number of excavations	Soil horizons		
		A	B	C
Native vegetation—				
Grassland	5	134.87	15.40	9.95
Meadow	2	84.50	3.46	1.80
Trees and shrub	3	72.87	12.80	2.89
Abandoned from cultivation—				
Naturally regrassed	5	75.64	13.32	8.36
Reseeded to grass	4	93.21	19.27	5.84
Perennial weeds	5	96.02	14.54	3.09
Cultivated	13	69.96	14.35	3.99
Mean thickness of horizon (in.)	—	8.5	19.5	20.0

An attempt to relate the total weight of underground parts of leafy spurge to that of the competing plant material in each monolith (Table 2) failed to indicate negative correlation, the correlation coefficient being -0.19 ($P = 0.25$). Furthermore, the correlation coefficient for the 26 samples excavated from land which had not been cultivated for at least one year prior to excavation was -0.36 ($P = 0.12$). This suggests that the competing species present were of no great effect in restricting the extent of the root system of the weed.

The effect of surface soil texture on the development of underground parts, as expressed by total weight, is small (Table 4). The average yield of ten samples in soils of loam texture or finer was 20.65 gm. as compared to a mean of 22.61 gm. for the 29 samples in soils of coarser texture. The surface layer of soil contained a larger proportion of plant material in the coarse soils (57.2 per cent) than in the finer ones (53.2 per cent). The proportion of the underground parts located in the 6- to 18-inch depths (29.7 per cent) was greater in the finer-textured soils than in the coarse soils (23.1 per cent). However, below 30 in. the proportion was again greater in the coarse soils.

In order to compare the extent of plant development in each soil horizon, which varied in depth between sites, the density (gm. per cu. ft.) of plant material was compiled for the A, B and C horizons. These data are grouped in Table 5 according to land use. The density of roots of leafy spurge is greatest in the A horizon in infestations which have invaded native vegetation and smallest in land which had been in cultivation within one year prior to the date of excavation. Less difference in density of plant parts was found in the B horizon under different land uses.

Distribution by Size of Underground Parts

Plant parts were represented by the five size classes indicated in Table 6. The finest materials (up to 0.5 mm. in diameter of cross-section) represented 30.5 per cent of the total weight of the roots, while pieces larger than 5 mm. comprised 19.8 per cent of the weight. The proportion of the weight furnished by the finest material was greatest in every layer (with one exception) and decreased with increasing size (Figure 2). The proportion of the weight in various layers which was provided by the finest material increased with depth from 23.1 to 56.8 per cent. This value for the plant parts 0.6 to 2.0 mm. in diameter increased from the surface to the 24- to 30-inch layer (from 18.2 to 43.5 per cent) and then

TABLE 6.—MEAN WEIGHT OF OVEN-DRY MATERIAL OF LEAFY SPURGE OF VARIOUS DIAMETERS OF CROSS SECTION TO A DEPTH OF 48 IN. BELOW 0.25 SQ. FT. OF SURFACE SOIL IN EACH OF 39 EXCAVATIONS. THE PERCENTAGE OF PLANT MATERIAL CONTRIBUTED BY EACH SIZE CLASS IS ALSO GIVEN

	Size classes (mm.)					Total
	0.0–0.5	0.6–2.0	2.1–5.0	5.1–10.0	Over 10.0	
Weight (gm.)	6.74	5.50	5.48	2.84	1.55	22.11
Percentage	30.5	24.9	24.8	12.8	7.0	100.0

TABLE 7.—MEAN WEIGHT AND DENSITY (GM. PER CU. FT.) OF UNDERGROUND PARTS OF LEAFY SPURGE OF VARIOUS SIZES (DIAMETER OF CROSS SECTION) IN EACH MAJOR SOIL HORIZON. DATA ARE FROM 37 EXCAVATIONS

Size classes (mm.)	Weight (gm.)				Density		
	A	B	C	Total	A	B	C
0 – 0.5	3.31	1.98	1.18	6.47	18.58	4.88	2.84
0.6– 2.0	2.65	1.97	1.01	5.63	14.92	4.85	2.42
2.1– 5.0	3.46	1.54	0.39	5.39	19.46	3.78	0.95
5.1–10.0	2.68	0.15	0.00	2.83	15.07	0.37	0.00
Over 10.0	1.12	0.13	0.00	1.25	6.26	0.33	0.00
Total	13.22	5.77	2.58	21.57	74.29	14.21	6.21

decreased (to 34.8 per cent), while the proportion contributed by the larger materials decreased with depth to the extent that the largest size was not found below 12 in. in the soil.

The weight of each size of plant material found in a layer of soil decreased with depth. This value generally increased with increased size in the uppermost layer and decreased with increased size in all other layers (Figure 2).

The mean quantity of plant parts of each size class found in each soil horizon is presented in Table 7. An abundance of fine roots is indicated in every horizon, while plant parts larger than 5.0 mm. were not found below the B horizon.

The effect of soil texture on the size of plant parts of leafy spurge in the major soil horizons is suggested in Table 8. The density of plant material in the A and B horizons was considerably greater in the soils of loam texture and finer, as compared with the sandier soils. In the C horizon, however, the density of plant parts was 1.9 times as great in the coarse soils as in the finer soils. The quantity of material less than 0.5 mm. and more than 5.0 mm. in diameter of cross section was greater in the coarse-textured soils, while the plant parts of intermediate size were more abundant in the fine soils.

The effect of land use on the relative distribution of various sizes of underground plant parts is suggested in Table 9. In cultivated land the proportion of the plant parts contributed by pieces of intermediate sizes (0.6 to 5.0 mm.) is increased (63.6 per cent) as compared to that in land which had never been cultivated (39.7 per cent). The other three size classes are proportionally less abundant in cultivated land than in land occupied by native vegetation. The relative abundance of plant parts of various sizes in abandoned land which has become naturally regrassed is similar to that in uncultivated land.

Depth of Root Penetration

Because the monoliths were removed only to a depth of 48 in. it was not possible to ascertain from them the extent of root penetration of leafy

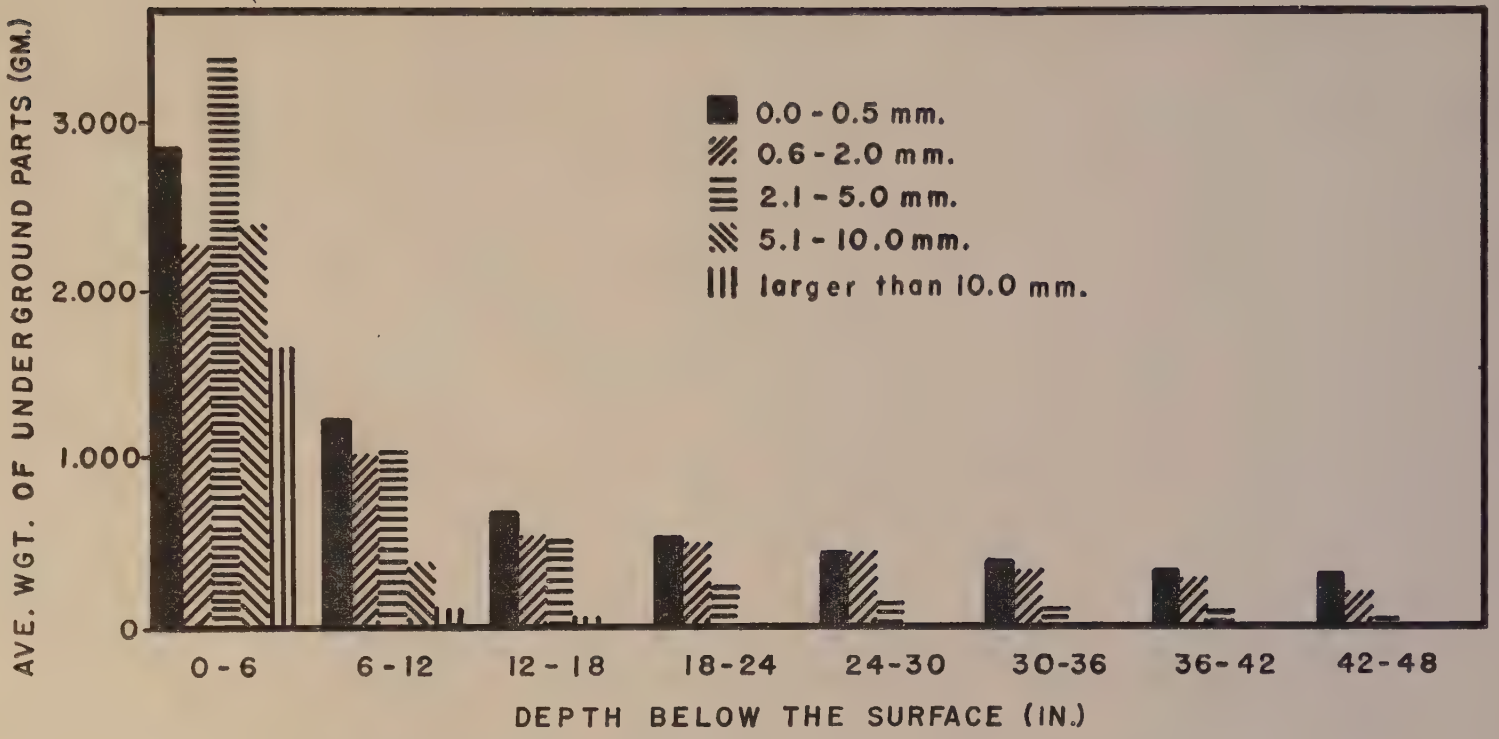

FIGURE 2. Histogram showing the mean weight of each of the five size classes of plant material of leafy spurge in each 6-inch layer of soil to a depth of 48 in. The data are from 39 excavations.

TABLE 8.—MEAN WEIGHT OF OVEN-DRY MATERIAL OF LEAFY SPURGE OF VARIOUS DIAMETERS OF CROSS SECTION IN EACH MAJOR SOIL HORIZON BELOW 0.25 SQ. FT. OF SURFACE. DATA FROM TEN SOILS OF LOAM TEXTURE AND FINER ARE COMPARED WITH THOSE FROM 27 SOILS OF COARSER TEXTURE THAN LOAM

Size classes (mm.)	Fine-textured soil				Coarse-textured soil			
	A	B	C	Total	A	B	C	Total
0 – 0.5	1.78	2.31	0.54	4.63	3.87	1.86	1.42	7.15
0.6– 2.0	2.30	3.17	0.51	5.98	2.79	1.53	1.18	5.50
2.1– 5.0	4.31	2.69	0.19	7.19	3.15	1.11	0.47	4.73
5.1–10.0	1.56	0.46	0.00	2.02	3.09	0.04	0.00	3.13
Over 10.0	0.34	0.49	0.00	0.83	1.40	0.00	0.00	1.40
Total	10.29	9.12	1.24	20.65	14.30	4.54	3.07	21.91
Mean thickness of horizon (in.)	5.6	25.8	16.6	—	9.6	17.2	21.2	—
Density (gm. per cu. ft.)	88.18	16.97	3.58	—	71.30	12.67	6.96	—

spurge below this depth. In all excavations except one (in native woodland of *Populus tremuloides* Michx.) the roots penetrated to 48 in. In 11 of the excavations, an attempt was made to discover how deeply the roots penetrated below this depth. Despite the difficulty of tracing the fine roots which occurred at this depth, they were followed to a depth of 63 in. or more in six excavations. Of the 11 excavations examined, the maximum depth of root penetration was 48 in. in two, between 48 and 63 in. in three, between 63 and 72 in. in five, and 98 in. in one. The ability of the roots to penetrate dense soil was noted in one site where they had grown through 30 in. of clay to reach a total depth of 50 in. The variation in maximum depths of penetration observed during this study could not be explained on the basis of differences in soil texture or land use.

DISCUSSION

The vertical distribution of the root system of a persistent perennial weed such as leafy spurge is important in relation to control. Success of depletion of underground food reserves by summerfallow or by grazing may be related to the location of those reserves. Effectiveness of soil sterilants in destroying underground plant tissue depends on the extent of the propagating and food storage tissue remaining below the depth to which a lethal quantity of the herbicide is leached in any particular soil. The effectiveness of plant competitors in control depends on the resulting decrease in extent of the underground parts of the weed.

The present study has indicated that in almost every instance the roots of leafy spurge penetrate to depths of 48 to 98 in. in Saskatchewan soils. The depth of accumulation of calcium carbonate in these soils suggests that leaching of soil sterilants cannot be expected to occur to the maximum depth of the roots or even to the maximum depth of development of reproductive buds (to be discussed in a later paper). The use of these herbicides can therefore be expected to leave live tissue below possibly two feet in the soil. This plant material is capable of producing shoots which may be able to reach the surface through adjacent unsterilized soil.

The considerable quantity of plant material in the soil (over four tons per acre) below infestations of leafy spurge probably accounts in part for the difficulty of effecting eradication by cultivation. The lower quantity of plant parts at all levels in cultivated land as compared with infested native grassland (Table 3) might suggest that disturbance has greatly affected root development. However, the root system in abandoned lands is not more vigorous below 6 in. in depth than in cultivated land, despite the lack of disturbance for a number of years. The effect of cultivation is apparently to reduce the proportion of the larger and smaller roots in relation to those of 0.6 to 5.0 mm. in diameter (Table 9). The extent of the development of underground parts is apparently affected principally in the A horizon under the extensive methods of cultivation which are characteristic on Saskatchewan farms.

Some authors have suggested that vigorously growing forage crops be used to choke out leafy spurge. The data presented here indicate that cultivation is more effective than a competing grass in reducing the vigour of the root system. The production of underground parts averaged 30.7

TABLE 9.—MEAN PERCENTAGE OF OVEN-DRY WEIGHT FURNISHED BY MATERIAL OF LEAFY SPURGE OF VARIOUS SIZES (DIAMETER OF CROSS SECTION) TO A DEPTH OF 48 IN. IN SOIL UNDER THREE MAJOR LAND USES

Land use	Number of excavations	Total weight (gm.)	Size classes (mm.)				
			0–0.5	0.6–2.0	2.1–5.0	5.1–10.0	Over 10.0
Native vegetation	10	28.35	32.0	20.2	19.5	17.6	10.7
Abandoned from cultivation	16	21.68	35.7	24.5	24.1	11.4	4.3
Cultivated	13	17.83	24.0	32.7	30.9	7.6	4.8

per cent greater under seeded grass (*Agropyron cristatum* (L.) Gaertn. and *Bromus inermis* Leyss.) than under cultivation (Table 2). The small amount of competing plant material indicated might suggest poor establishment of grass. However, the stands of grass were very vigorous but had not yet invaded the patches of leafy spurge. In older stands of grass the patches of weed may become invaded, but the weed will probably not be killed. Usually the rate of spread is only checked. In this respect it is interesting to note the lack of ability of stands of native grasses to compete with leafy spurge. The quantity of roots of leafy spurge in native grassland averaged 39.91 gm. per sample and in naturally regrassed abandoned land 24.66 gm. These values compared with 16.52 gm. in abandoned land not yet regrassed (Table 2). The percentage of the root system found in the respective 6-inch layers varied no more than one per cent between cultivated land and land seeded to forage grasses. All other competitive vegetation permitted a larger proportion of the growth of the weed in the surface layer (Table 3).

The relatively small mean difference in amount of underground parts by total weight in soils of fine and coarse texture suggests that any difference in response to control in different soils is not due to this factor. However, the larger amount of plant material occurring below 2 ft. in coarse soils (Table 4) may be significant in explaining the apparently greater ease of control of leafy spurge which has been observed by the authors in clay soils as compared to sandy areas. A further explanation of this difference in response to control may be found in the smaller quantity of plant material of the larger sizes in fine soils (Table 8). The distribution of various sizes of underground plant parts (Tables 6, 7 and 8 and Figure 2) may be of considerable importance in relation to food storage. The authors are not aware of any reports which indicate whether or not underground parts of different diameters of cross section have storage capacities in proportion to their volume.

The high variability even among root samples taken from the same site makes difficult the statistical interpretation of the effect of different habitats on root development. The present study serves as a foundation for other papers which are to follow concerning leafy spurge and other persistent perennial weeds.

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CHANGES IN ORGANIC MATTER AND CERTAIN OTHER SOIL CONSTITUENTS IN FORTY YEARS OF CROPPING UNDER IRRIGATION[1]

R. F. Bishop and H. J. Atkinson

Science Service, Canada Department of Agriculture, Ottawa

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ABSTRACT

In 1911 a 10-year rotation, including 6 years of alfalfa, was laid down under irrigation at Lethbridge, Alberta. Soil samples were taken at the beginning of the experiment and again in 1922, 1940 and 1951. During the 40-year period the soil has become more alkaline but no significant changes occurred in respect to the phosphorus and potassium status of the soil. There have been significant increases in total nitrogen and organic matter content. In terms of the 1911 values, the nitrogen increased by 7.0 per cent and the organic matter by 10.5 per cent in the surface 6 inches. At the 6- to 12-inch depth, the increases were 42.5 and 45.2 per cent, respectively.

INTRODUCTION

The effect of cultivation and cropping on the organic matter content of soils in the Brown, Dark Brown and Black soil zones (9) of western Canada has long been of considerable interest. Shutt (8) in 1925 and Caldwell, Wyatt and Newton (2) in 1939 presented results showing changes that occurred at various locations over a period of years. Of a number of field experiments which would have been suitable for studying this point, few are still in progress in which soil samples were taken at the beginning of the experiment and at intervals since that time. One experiment which fulfills these conditions is located at the Experimental Station, Lethbridge, Alberta, and is known as Rotation "U".

Results on the composition of soil samples from Rotation "U" have been given in a number of publications. Shutt (8) determined the nitrogen and organic matter content of samples collected in 1911 and 1922 but made no mention of the methods used in making the determinations. Caldwell, Wyatt and Newton (2) reported on the nitrogen and carbon contents and the carbon : nitrogen ratio of samples from this rotation and from an adjacent virgin area. Hopkins and Leahey (6) made reference to the nitrogen content of samples collected in 1922 and in 1940. Hill (4) referred to analytical results for samples collected at various intervals but the analyses were made in three different laboratories.

The results in this paper were obtained in 1952 on soil samples collected in 1911, 1922, 1940 and 1951 and it is believed that the data are directly comparable. As far as can be determined, all samples were taken in a similar manner. The results are those of a single analyst, thus reducing errors that could be attributed to different workers and to variations in analytical procedures in different laboratories over intervals of several years.

[1] Presented at a meeting of the Soils Section, Agricultural Institute of Canada, Saskatoon, Saskatchewan, June 24, 1953. Scientific Contribution No. 241, Chemistry Division, Science Service.

OUTLINE OF THE EXPERIMENT

Rotation "U" was begun in 1911 on irrigated land at the Experimental Station, Lethbridge, Alberta. The soil is a Dark Brown loam developed on alluvial-lacustrine material. The experiment was reviewed by Hill (4) in 1951 when yield data were summarized and discussed. It consists of a 10-year rotation of oats, barley, sugar beets, spring wheat and 6 years of alfalfa on 10 one-acre plots. From 1911 to 1923 the intertilled crop was potatoes rather than sugar beets and while there have been some changes in crop sequence all crops have been grown each year. Originally, barnyard manure was applied at 12 tons per acre once in the 10-year cycle but, in 1942, this was increased to 30 tons per acre, one-half of which was applied to the barley stubble and one-half to the second year of alfalfa. In both cases the manure was applied in the fall. No commercial fertilizer was used until 1933 when the plots were divided and an 11-48-0 fertilizer at 100 lb. per acre was applied for sugar beets, first-year alfalfa and fourth-year alfalfa on the south half of each original plot.

MATERIALS AND METHODS

Composite soil samples, representative of the 0-6 and 6-12 inch depths, were collected from each of the original plots in 1911 and again in 1922. Similar samples were obtained from both the fertilized and unfertilized sections in 1940 and in 1951. In 1952, pH values, total nitrogen and organic matter were determined on all samples. In addition the samples taken at the 0-6 inch depth in 1911 and in 1951 were analysed for exchangeable potassium and so-called available phosphorus.

The determination of pH value was made with a glass electrode using a soil : water ratio of 1 : 2.5. Organic matter was determined by chromic acid oxidation (7) and total nitrogen by the Kjeldahl method. Exchangeable potassium was obtained by extraction with neutral normal ammonium acetate (10). Estimates of the available phosphorus content were made by Bray's method for adsorbed and easily acid-soluble phosphorus (1) as well as by extraction with a 1 per cent K_2CO_3 solution as proposed by Das (3) and modified by Hockensmith *et al.* (5).

TABLE 1.—CHANGES IN TOTAL NITROGEN AND ORGANIC MATTER
(Mean values for ten plots—moisture-free basis)

Description	Nitrogen (N)		Organic matter	
	0-6 inches	6-12 inches	0-6 inches	6-12 inches
	%	%	%	%
1911—Original	0.186	0.134	2.95	1.88
1922	0.179	0.149	2.40	1.86
1940—North (unfertilized)	0.199	0.171	3.12	2.50
1951—North (unfertilized)	0.209	0.191	3.26	2.73
L.S.D. at P = 0.05	0.013	0.017	0.39	0.41

RESULTS AND DISCUSSION

The values for total nitrogen and organic matter in plots receiving no commercial fertilizer are summarized in Table 1. There was no significant change in total nitrogen content at either sampling depth during the first 10 years of the experiment but the 1940 and 1951 values were greater than those for 1911 or 1922. There was also an increase between 1940 and 1951 at the 6-12 inch depth. The organic matter content of the surface six inches decreased from 1911 to 1922 but increased between 1922 and 1940 and between 1922 and 1951. At the 6-12 inch depth the 1940 and 1951 values were greater than those for 1911 or 1922. Analyses of samples taken in 1940 and 1951 on the fertilized halves of the plots showed the same trend in nitrogen and organic matter content.

In terms of the 1911 values there was a 7 per cent increase in nitrogen content in the surface 6 inches and a 42.5 per cent increase at the 6-12 inch depth during the 40-year period. Increases in organic matter content, calculated in a comparable manner, were 10.5 per cent for the surface 6 inches and 45.2 per cent at the 6-12 inch depth. In 1911 the carbon: nitrogen ratios were 10.9 and 12.3 at the 0-6 and 6-12 inch depths, respectively. The corresponding values in 1951 were 11.1 and 12.1.

The mean values for pH, exchangeable potassium and available phosphorus for samples taken in 1911 and 1951 are presented in Table 2. There has been a significant increase in soil alkalinity in the surface 6 inches during the 40-year period but differences in pH values at the 6-12 inch depth were not significant. In regard to the phosphorus and potassium values none of the differences between years or between the fertilized and unfertilized sections attained significance. In respect to the phosphorus values the results obtained by both methods presented the same general picture.

TABLE 2.—CHANGES IN REACTION AND IN CONTENT OF SOLUBLE PHOSPHORUS AND EXCHANGEABLE POTASSIUM

(Results for P and K expressed on an air dry basis)

Description	Depth	pH		Phosphorus (P)				Potassium (K)	
		Mean	S.E.*	Bray		K_2CO_3		Mean	S.E.*
				Mean	S.E.*	Mean	S.E.*		
	in			p.p.m.		p.p.m.		p.p.m.	
1911—Original	0– 6	7.45	0.07	61.4	2.65	37.4	1.15	316.6	5.99
	6–12	7.68	0.15						
1951—North (unfertilized)	0– 6	7.80	0.04	66.7	6.89	35.3	2.98	292.9	13.04
	6–12	7.82	0.04						
1951—South (fertilized)	0– 6	7.89	0.04	71.8	7.08	39.8	2.79	296.1	13.04
	6–12	7.88	0.17						

* S.E. = standard error of mean of 10 plots (P = 0.05).

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SEAWEED MEAL IN THE RATION FOR BACON HOGS[1]

C. D. T. Cameron[2]

Experimental Farm, Nappan, Nova Scotia

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ABSTRACT

A study was undertaken to determine the effects on growth, feed efficiency, and carcass quality of adding seaweed meal, (mainly *Ascophyllum nodosum*), to the growing and fattening rations for bacon hogs. A total of 72 pigs of comparable breeding were fed individually, in three tests involving 12 animals on each of six rations.

There was no significant difference in growth rate or carcass quality between the pigs receiving comparable rations with or without seaweed meal or between the pigs receiving 2, 4, or 6 per cent of this product in the ration.

A recent extensive survey of the seaweeds of the southwest shores of Nova Scotia (2) has revealed a very large tonnage of fucoids, laminarias, and *Chondrus* spp. The possibility of utilizing this material as a feed for live stock is of considerable economic importance in the development of the seaweed industry.

A number of experiments have been reported on the value of European seaweeds as a feed for hogs, but there is no information on the possible effect of seaweeds on the quality of the carcass.

Experiments reported by Lunde, and summarized by Woodward (7), show that the addition of 5 to 10 per cent of seaweed meal to the ration of hogs and horses was beneficial. Larger quantities of seaweed meal had to be used with caution because of its high iodine and mineral content. Seaweed meal harvested in the spring had a higher food value for pigs than hay, and seaweed collected in the autumn had a food value between that of hay and oats. Ringen (5) reported a similar feeding value for seaweeds but found a lower digestibility for pigs than for sheep. *Laminaria* meal was better than that made from *Fucus* and there was a great seasonal variation in composition. It was recommended that seaweed be harvested in late summer.

Digestibility trials with pigs and sheep at the Rowett Research Institute (6, 7), in which *Ascophyllum nodosum* and *Laminaria saccharina* were substituted for 25 per cent of the normal ration, showed negative digestibility in some cases. The littoral weeds were found to have a lower digestibility than the sub-littoral weeds tested.

The object of the study reported herein was to investigate the value of Atlantic seaweed meal in growing and fattening rations for bacon hogs. The seaweed meal was supplied through the courtesy of the National Sea Products Limited, Halifax, Nova Scotia. This product was harvested during the month of November and was largely *Ascophyllum nodosum* with a very small percentage of *Fucus vesiculosus*. The chemical analyses of this material was reported by MacIntyre and Jenkins (3) as follows:— Moisture, 7.43 per cent; protein (N × 6.25), 6.40; ether extract, 1.55; crude fibre, 9.37; ash, 20.13; calcium, 1.29; phosphorus, 0.12; iodine, 0.26; salt (NaCl) 2.00.

[1] Contribution from Animal Husbandry Division, Experimental Farms Service, Canada Department of Agriculture.

[2] Agricultural Research Officer.

EXPERIMENTAL

Seventy-two purebred Yorkshire pigs from the herd of the Experimental Farm at Nappan, N.S., were used in this trial. The pigs in the first replicate were all sired by the same boar and out of sows related to the dams of the pigs in the other two replicates. The pigs in the last two replicates were sired by another boar and out of litter mate sows, all qualified in Advanced Registry. The pigs were started on trial upon reaching a weight of 40 to 50 pounds and were fed to a weight of approximately 200 pounds. Two castrate male and two female pigs were allotted to each ration group in each replicate. Within these restrictions, the pigs were allotted at random to individual pens, 12 pigs on each of six rations.

All pigs received two rations; a growing ration was given until they reached 100-110 pounds live weight, and the pigs were then changed individually to a fattening ration until they reached market weight.

The ration combinations fed are shown in Table 1. The proportions of tankage and fish meal given are for the growing period. During the fattening period tankage and fish meal were reduced to 8 per cent and 5 per cent, respectively, with a corresponding increase in barley.

TABLE 1.—COMPOSITION OF RATIONS

Feed	Lots					
	1	2	3	4	5	6
	lb.	lb.	lb.	lb.	lb.	lb.
Barley	83.0	81.0	79.0	78.0	90.0	88.0
Tankage	16.0	16.0	16.0	16.0	—	—
Fish meal	—	—	—	—	9.0	9.0
Ground limestone	0.5	0.5	0.5	—	0.5	0.5
Salt	0.5	0.5	0.5	—	0.5	0.5
Seaweed meal	—	2.0	4.0	6.0	—	2.0

Each pig received daily one-half ounce of a feeding fish oil of 1500A and 200D potency while on the A ration.

The dry meal allowance was placed in each trough and sufficient water poured over it to make a slop. Additional water was provided between meals. All pigs were fed by hand to the limit of their appetite. Each pig was fed three times daily during the first feeding period and twice daily thereafter.

The individual weights of the pigs and their feed consumption were recorded fortnightly. Pigs were marketed upon reaching a weight of about 200 pounds. All hog carcasses were rail graded, measured, and scored by the Canada Live Stock Hog Graders according to the procedure followed for carcasses of hogs from Advanced Registry Feeding Stations (4).

RESULTS AND DISCUSSION

The results of this test are presented and discussed in three sections: the growing period, the total feeding period, and the carcass data.

The Growing Period

The data recorded for the pigs up to a weight of 100-110 pounds were analysed separately in order to study possible differences between rations during the growing and finishing periods. The results of the analyses of variance and co-variance of these data are given in Table 2.

TABLE 2.—AVERAGE DAILY GAIN IN LIVE WEIGHT AND AVERAGE DAILY FEED CONSUMPTION OF PIGS TO 100-110 POUNDS

Treatment	Number of pigs	Average daily feed consumption	Average daily gain	
			Observed	Adjusted[1]
		lb.	lb.	lb.
Lot 1— Tankage, no seaweed meal	12	4.01	1.23	1.24
Lot 2— Tankage, 2 per cent seaweed meal	12	4.23*	1.25	1.24
Lot 3— Tankage, 4 per cent seaweed meal	12	4.04	1.19	1.19
Lot 4— Tankage, 6 per cent seaweed meal	12	4.26*	1.27*	1.26
Lot 5— Fish meal, no seaweed meal	12	4.05	1.42*	1.42*
Lot 6— Fish meal, 2 per cent seaweed meal	12	4.03	1.39*	1.39*
Replicate 1	24	4.06	1.21	1.22
Replicate 2	24	4.00	1.31*	1.32*
Replicate 3	24	4.25*	1.36*	1.34*
Female	36	4.06	1.27	1.27
Male	36	4.15	1.31	1.31
General average (n = 72)	—	4.10	1.29	1.29
Necessary difference (P = 0.05)—				
Between lots of 12	—	0.17	0.08	0.08
Between lots of 24	—	0.12	0.06	0.06
Between lots of 36	—	0.10	0.05	0.05

[1] Adjusted to average initial weight and feed intake.
* Significantly greater than comparative groups.

In order to eliminate the effect of differences in initial weight and feed intake, the gains were adjusted statistically, to the average initial weight and average feed consumption. On this basis seaweed meal showed no significant effect on the gains up to a weight of 100-110 pounds, regardless of the percentage of seaweed meal included in the ration.

The superiority of fish meal over tankage as a protein supplement is evident from the 13 per cent average increase in growth rate of Lots 5 and 6 over Lots 1 and 2.

Total Feeding Period

The data recorded for the total feeding period were analysed according to the same procedure as for the growing period. These results are shown in Table 3.

TABLE 3.—SUMMARY OF GAINS AND FEED CONSUMPTION—TOTAL FEEDING PERIOD

Treatment	Number of pigs	Average daily feed consumption	Average daily gain	
			Observed	Adjusted[1]
		lb.	lb.	lb.
Lot 1— Tankage, no seaweed meal	12	5.65	1.48	1.49
Lot 2— Tankage, 2 per cent seaweed meal	12	5.86	1.52	1.52
Lot 3— Tankage, 4 per cent seaweed meal	12	5.76	1.48	1.49
Lot 4— Tankage, 6 per cent seaweed meal	12	6.11*	1.48	1.45
Lot 5— Fish meal, no seaweed meal	12	5.82	1.61*	1.61*
Lot 6— Fish meal, 2 per cent seaweed meal	12	5.65	1.63*	1.64*
Replicate 1	24	5.83	1.45	1.45
Replicate 2	24	5.69	1.55*	1.56*
Replicate 3	24	5.91*	1.60*	1.59*
Female	36	5.72	1.51	1.52
Male	36	5.90*	1.56*	1.55
General average (n = 72)	—	5.81	1.53	1.53
Necessary difference (P = 0.05)—				
Between lots of 12	—	0.22	0.08	0.08
Between lots of 24	—	0.16	0.05	0.05
Between lots of 36	—	0.13	0.04	0.04

[1] Adjusted to average initial weight and feed intake.
* Significantly greater than comparative groups.

TABLE 4.—SUMMARY OF MEAN CARCASS MEASUREMENTS

Treatment	Number of pigs	Average numerical grading value	Total carcass score	Score for belly (Perfect score 20)	Area of loin muscle	Length	Back fat	Shoulder fat	Loin fat	Shoulder	Middle	Ham
					sq. in.	in.	in.	in.	in.	%	%	%
Lot 1—												
Tankage, no seaweed	12	2.25	77.5	17.8	4.24	30.9	1.00*	1.87	1.54*	27.0	48.6	24.3
Lot 2—												
Tankage, 2 per cent seaweed	12	2.75	78.4	17.5	4.22	31.0	0.96	1.85	1.47	26.9	49.0	24.1
Lot 3—												
Tankage, 4 per cent seaweed	12	2.58	78.7	17.0	4.14	31.0	0.92	1.84	1.45	26.9	48.8	24.3
Lot 4—												
Tankage, 6 per cent seaweed	12	2.58	80.3	17.8	4.18	31.0	0.86	1.77	1.43	26.6	49.2	24.2
Lot 5—												
Fish meal, no seaweed	12	2.42	77.6	18.0	4.26	30.8	0.92	1.77	1.45	26.9	48.9	24.2
Lot 6—												
Fish meal, 2 per cent seaweed	12	2.58	83.3	17.2	4.45*	31.0	0.96	1.77	1.41	27.0	48.9	24.1
Replicate 1	24	2.58	74.7	17.4	4.35*	30.3	0.96	1.83	1.45	26.9	49.1	24.0
Replicate 2	24	2.54	81.3*	17.7	4.29*	31.3*	0.90	1.76	1.44	26.9	48.6	24.5*
Replicate 3	24	2.46	81.9*	17.5	4.10	31.3*	0.95	1.85*	1.49	26.7	49.0	24.2
Female	36	2.72	82.9*	18.0*	4.42*	31.0	0.87	1.77	1.39	27.0	48.5	24.5*
Male	36	2.33	75.7	17.1	4.08	30.9	1.00*	1.86*	1.53*	26.8	49.3*	23.9
Necessary difference (P = 0.05)—												
Between groups of 12	—	—	7.13	1.47	0.23	0.38	0.11	0.12	0.11	0.62	0.78	0.54
Between groups of 24	—	—	5.05	1.04	0.16	0.27	0.08	0.08	0.08	0.44	0.55	0.39
Between groups of 36	—	—	4.12	0.85	0.13	0.22	0.06	0.07	0.06	0.36	0.45	0.31

* Significantly greater than comparative groups.

When the whole feeding period was considered the differences observed between the various groups were generally the same as those which occurred during the growing period.

The feed intake was significantly greater for the pigs in Lot 4. The addition of seaweed meal at the maximum level used in this experiment, apparently stimulated greater feed consumption without a concurrent increase in rate of gain.

No adverse effects of any kind in the general condition of the pigs were observed from the feeding of seaweed meal and the rate of gain compared favourably with the standard growth curve, shown by Cameron *et al.* (1) for pigs in this herd.

It would appear from the results of these trials that from 2 to 6 per cent of seaweed meal, of the type used in this experiment, may be added safely to the hog ration, although no increase in growth rate will occur when this product is added to a balanced ration. In view of the performance of the pigs in Lot 4, it would appear that the addition of a mineral supplement is not necessary when 6 per cent of seaweed meal is included in the feed mixture.

Carcass Quality

Table 4 summarizes the carcass data recorded for the three trials.

The rail grading value of the carcasses was calculated on the basis of a value of three for grade A; two for grade B_1, and one for grade C. These values and the mean total carcass scores showed little difference in carcass quality between the control and the pigs receiving 2, 4, or 6 per cent of seaweed meal. However, the pigs on the ration containing 6 per cent seaweed meal, without a mineral supplement, showed a significantly smaller depth of back fat and loin fat than the "tankage—no-seaweed meal" pigs.

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GANGRÈNES DU FRAISIER[1]

ALBERT PAYETTE[2]

Laboratoire du Service des Sciences, Ste-Anne-de-la-Pocatière, Québec

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ABSTRACT

Strawberry gangrenes are progressive necroses consisting of indefinite, brown or black lesions on any part of the strawberry plant. They are particularly severe on plants growing under unfavourable conditions.

Isolations made from gangrenous lesions on strawberry plants from early spring to late fall during two consecutive years revealed the presence, in varying amounts, of unidentified bacteria and nematodes, and of fungi belonging to the genera *Botrytis*, *Chaetomium*, *Coniella*, *Coniothyrium*, *Fusarium*, *Gloeosporium*, *Mucor*, *Phoma*, *Rhizoctonia*, *Rhizopus*, *Septoria*, *Sporocybe* (*Petriella*), *Trichoderma*, *Zythia* (*Gnomonia*) and a few others.

Healthy plants for pathogenicity tests were obtained by transferring cuttings from vigorous runners into sterilized moist sand.

Of all isolates tested for pathogenicity, only *Botrytis* sp. of the *cinerea* type and *Rhizoctonia* sp. of the *solani* type could rapidly attack and destroy every part of the strawberry plant.

INTRODUCTION

Depuis qu'on a voulu restaurer la culture du fraisier, après la première guerre mondiale (1, 2, 9, 12), on parle de la dégénération du fraisier. Au lieu de produire en quantité pendant plusieurs années des fraises de qualité, les fraisières se gâtent généralement en moins de trois ans.

Les phytopathologistes se sont demandé si des virus, des bactéries, des nématodes ou des champignons ne seraient pas les causes de ce déclin. La mise en lumière de plusieurs maladies du fraisier a beaucoup facilité l'approche du problème, désormais confiné principalement au "désordre complexe" qu'on est convenu d'appeler la "pourriture noire des racines" (2, 4, 13, 16).

Nous avons constaté que cette pourriture noire des racines du fraisier peut être une manifestation de maladies capables d'affecter chaque partie de la plante et de se propager par contage. Nous englobons sous l'appellation "gangrènes du fraisier" ces maladies qui font l'objet du présent travail et qui peuvent être causées par des champignons appartenant aux groupes représentés par *Rhizoctonia solani* Kühn et *Botrytis cinerea* Pers.

Les gangrènes du fraisier se manifestent par des lésions imprécises, envahissantes, sur n'importe quelle partie de la plante, dont les tissus infectés finissent par prendre une couleur brune ou noirâtre.

HISTORIQUE

Berkeley (2), en 1934, souligna l'importance, la généralisation et la complexité du phénomène de la pourriture des racines du fraisier.

Miller (13), en 1947, mentionna les organismes du sol, les conditions défavorables d'hivernement, de sol, de toxines dans le sol, d'entreposage et de manutention défectueuse avant la plantation comme autant de facteurs impliqués dans la pourriture noire des racines du fraisier.

[1] Contribution no. 1289 de la Division de la Botanique et de la Phytopathologie, Service des Sciences, Ministère de l'Agriculture, Ottawa, Canada.

[2] Phytopathologiste.

Butler et King (4), en 1951, rappelèrent que plusieurs champignons saprophytes ou faiblement parasitaires semblent être associés à la pourriture des racines du fraisier. Des champignons appartenant aux genres *Alternaria*, *Asterocystis*, *Coniothyrium*, *Cylindrocarpon*, *Cylindrocladium*, *Diplodia*, *Diplodina*, *Fusarium*, *Hainesia*, *Olpidium*, *Pachybasidium*, *Phytophthora*, *Pythium*, *Ramularia*, *Rhizoctonia*, *Stemphylium*, *Verticillum* (2, 4, 10, 13, 16) et d'autres ont été tenus plus ou moins responsables de la pourriture noire des racines du fraisier. Il est à noter que *Rhizoctonia solani* fut le plus souvent mentionné sous ce rapport (2, 4, 10, 11, 13, 16, 17, 18).

Si l'on considère les diverses maladies du fraisier attribuées à *Rhizoctonia solani*, on constate que toute la plante est sujette aux attaques de ce champignon (3, 7, 8, 18). Stevens (15), en 1925, nota que *Botrytis* ne limite pas ses méfaits aux fruits, mais qu'il peut attaquer aussi les pétioles, les fleurs et les hampes florales et, de cette façon, endommager toute la plante. Bien qu'on ait trouvé maintes fois *Botrytis* (2, 13) associé à des lésions sur les racines du fraisier, on ne semble guère l'avoir soupçonné de pouvoir attaquer les racines.

Dans le sud des États-Unis, Nolan (14), en 1932, rapporta une maladie attribuée à *Sclerotium rolfsii* et qui nous paraît être une nécrose progressive, une véritable gangrène du fraisier.

En consultant les rapports d'enquête sur les maladies des plantes au Canada (6), on constate que la pourriture noire des racines du fraisier est très répandue au pays et qu'on s'est perdu en conjectures sur les causes possibles. Dans la province de Québec, devant pareille situation, Caron (5), en 1949, conclut que le mal, qu'il nomma "affaissement" du fraisier, est d'ordre purement écologique.

Vers le même temps, des tournées d'enquête à travers la Province nous avaient persuadé qu'il est difficile de trouver un champ de fraises complètement exempt de gangrène sous une forme quelconque.

DESCRIPTION DE LA MALADIE

Voici comment les gangrènes du fraisier nous ont paru se présenter le plus souvent. L'année de la plantation, on peut voir, durant presque toute la saison de végétation, des fraisiers succomber çà et là. Les racines secondaires sont absentes et les racines primaires ne sont plus qu'une pourriture brune ou noirâtre. L'année suivante, même après un bon départ de la végétation, on peut noter certaines détériorations qu'on attribue généralement au froid hivernal et que peuvent être de nature gangréneuse.

Vers le temps de la cueillette, d'autres plantes s'affaissent, et souvent il se forme dans la plantation des "ronds" ou plages brunies, comme touchées par le feu, qui peuvent s'étendre assez rapidement. En d'autres endroits, on note parfois une teinte bronzée ou rougeâtre du feuillage; l'examen des racines montre qu'elles sont partiellement affectées. On remarque aussi des lésions brunâtres ou noirâtres sur les stolons et les pétioles. Des lésions de couleur cannelle se forment souvent aux points de contact de fruits moisis avec d'autres organes.

Quelques semaines après avoir transplanté en serre, dans du terreau stérilisé, des fraisiers apparemment sains provenant de l'École Supérieure d'Agriculture, on pouvait observer sur les stolons et les pétioles des lésions profondes, de couleur brun foncé à noirâtre. Plusieurs stolons et pétioles étaient complètement étranglés. Avant de s'affaisser, les feuilles dont le pétiole était attaqué prenaient généralement une teinte bronzée ou rougeâtre. Il s'est aussi formé sur plusieurs feuilles des lésions extensives qui rendaient les tissus flasques et comme "brûlés" par le froid. On pouvait encore noter la pourriture des bourgeons et constater la présence de lésions noirâtres sur les racines.

Un autre cas intéressant s'est présenté dans la serre. Quelque trois cents fraisiers importés de Californie avaient été transplantés dans du terreau et des pots stérilisés. Les tables avaient été désinfectées et les arrosages faits à l'eau distillée. Trois semaines après la plantation, une épiphytie détruisit environ dix pour cent des plantes. Des lésions extensives, de couleur brun pâle à brun cannelle et portant d'innombrables fructifications de *Botrytis* sp. du type *cinerea* pouvaient s'observer sur le pétiole et le limbe des feuilles. Nombre de feuilles s'affaissaient. Les racines présentaient des lésions analogues sur lesquelles on pouvait reconnaître *Botrytis*. A la mort des plantes, les racines pourries étaient noirâtres.

MÉTHODES EXPÉRIMENTALES

Pour l'isolement des organismes concernés, nous avons choisi, à des endroits divers, durant deux annés consécutives, depuis le début du printemps jusque tard l'automne, des fraisiers peu affectés dont les racines, les tiges, les coulants ou les feuilles présentaient des lésions gangréneuses. Nous en avons prélevé des fragments que nous rincions à l'eau courante et distillée et que nous trempions ensuite durant quelques secondes dans de l'alcool éthylique à soixante-dix pour cent, puis dans du bichlorure de mercure à raison d'une partie dans mille et, finalement, dans une solution fraîche d'hypochlorite de calcium à dix pour cent. Nous disposions alors quatre ou cinq des fragments ainsi traités dans une même boîte de Petri, sur de la gélose au maïs ou à la pomme de terre. Les cultures microbiennes croissaient à la température et à la lumière diffuse du laboratoire. Au bout de quelque temps, nous pouvions obtenir des cultures pures de plusieurs microorganismes.

Pour mieux caractériser certains champignons, nous les avons cultivés alternativement sur gélose au maïs ou à la pomme de terre avec ou sans dextrose.

L'examen microscopique permit d'identifier les champignons qui se montraient le plus souvent ou qui semblaient présenter plus d'intérêt. Nous n'avons accordé que peu d'attention aux organismes qui n'apparaissaient pas régulièrement, quelle qu'ait pu être leur fréquence en certaines occasions exceptionnelles. Par contre, certains microorganismes pouvaient n'émerger qu'en proportion insignifiante, mais avec constance, dans les divers essais, et mériter, de ce fait, plus de considération.

Les organismes que se sont manifestés le plus régulièrement à partir de lésions gangréneuses de fraisiers de diverses provenances furent, outre les bactéries et les nématodes, des champignons appartenant aux genres *Botrytis*, *Chaetomium*, *Coniella*, *Coniothyrium*, *Fusarium*, *Gloeosporium*, *Mucor*, *Phoma*, *Rhizoctonia*, *Rhizopus*, *Septoria*, *Sporocybe*, *Trichoderma* et *Zythia* (*Gnomonia*).

L'inoculation consistait le plus souvent à mettre en contact, par manipulation directe, certaines parties de la plante avec des cultures sur blé et avoine stérilisés des organismes à l'étude.

Pour diminuer les dangers de contamination, nous avons utilisé des cages de verre. Une cage mesurant 1.77 m. de long par 76 cm. de large et 1.17 m. de haut était fermée à sa partie supérieure par une toile de coton. Sept. petites cages de 75 cm. de long par 46 cm. de large et 41.5 cm. de haut pouvaient être recouvertes de verre ou de toile à leur partie supérieure.

Les tables, les pots, les soucoupes et les cages étaient désinfectés au sulfate de cuivre et à la formaline. Une couche de tourbe stérilisée de quatre ou cinq centimères d'épaisseur couvrait le fond des cages. Du terreau et du sable de grève stérilisés à la vapeur ont été tour à tour employés comme substratum.

Des fraisiers des variétés Campbell et Sierra, importés de Davis, Californie, furent adoptés pour nos essais. Avant d'être empotés pour une expérience, les fraisiers étaient lavés et examinés. Il était nécessaire d'en rejeter un nombre considérable du fait qu'ils pouvaient avoir quelques lésions gangréneuses.

Des boutures de fraisier cultivé furent obtenues en coupant aux ciseaux les coulants à une dizaine de centimètres de la jeune pousse. Après un bref séjour dans l'eau, ces boutures étaient empotées dans du sable lavé et maintenu humide par de fréquents et peu abondants seringages. Nous pouvions ainsi nous procurer en un temps relativement court des fraisiers propres à nos essais.

Nous avons utilisé aussi des fraisiers sauvages pour nos tests. Les fraisiers avariés étaient amputés de leurs parties malades et disposés dans des flacons d'Erlenmeyer remplis d'eau, puis, transplantés en divers milieux tels que différents types de sol, de la tourbe, du terreau, de la mousse de sphaigne et des mélanges variés. C'est le sable débarrassé de déchets organiques et maintenu humide qui s'est avéré le milieu le plus favorable à l'obtention de fraisiers sains.

ESSAIS DE PATHOGÉNICITÉ

I

Des cultures sur blé et avoine de bactéries, nématodes, et champignons appartenant aux genres *Botrytis*, *Coniothyrium*, *Fusarium*, *Gloeosporium*, *Zythia*, *Phoma*, *Rhizoctonia*, *Septoria* et *Sporocybe* (*Petriella*) furent disposées à la surface de pots de dix centimètres remplis de sable lavé et dans lesquels nous avions transplanté des fraisiers sauvages sains pour un test préliminaire de pathogénicité sur des tables de la serre.

Chaque traitement comportait trois pots. Les témoins reçurent des grains d'avoine et de blé stérilisés, tandis qu'un surplus de pots n'eurent que l'eau des arrosages.

Des divers organismes à l'essai, seul *Botrytis* sp. du type *cinerea* put attaquer les fraisiers dans les conditions de cette expérience.

Des lésions brun cannelle se formèrent aux points de contact des grains contaminés de *Botrytis* avec les parties exposées. Au bout d'une dizaine de jours, ces lésions avaient gagné certains pétioles, qui s'affaissaient, le limbe de quelques feuilles, les racines. Les racines secondaires d'une plante ainsi traitée étaient absentes et les racines primaires, pourries et noircies. Une autre plante avait les racines brunies à la partie supérieure et encore intactes à l'extrémité inférieure. Le troisième fraisier, sur lequel l'infection avait plus tardé à s'établir à partir de la plaie faite au stolon par les ciseaux, avait un pétiole atteint et des racines brunies au voisinage de cette plaie seulement. Les autres fraisiers étaient indemnes, sauf quelques individus manifestement contaminées par *Botrytis*. *Botrytis* sp. du type *cinerea* semblait donc capable d'attaquer aussi bien les racines que les autres parties du fraisier.

Les cultures de plusieurs microorganismes inclus dans ce test, telles celles de *Rhizoctonia solani*, se sont desséchées à la surface des pots sans avoir pu prendre suffisamment contact avec les plantes.

II

Pour parer à de telles difficultés, savoir, le danger de contamination et le dessèchement rapide de l'inoculum, nous avons poursuivi dans les cages de verre et avec terreau les tests préliminaires subséquents de pathogénicité de la plupart des organismes isolés antérieurement. Des fraisiers sains de la variété Campbell servirent à ces essais. Vingt pots de 23 cm. (9″) avec soucoupes et huit pots de 13 cm. (5″) sans soucoupe occupaient la grande cage. Deux gros pots et deux petits contenaient les témoins, et les divers traitements comprenaient trois pots chacun. Trois petits pots reçurent un mélange des bactéries isolées, et trois autres eurent des cultures de nématodes associés à des bactéries. *Mucor* sp. et *Rhizopus nigricans* furent ensemencés en mélange dans un traitement, quelques lignées de *Fusarium* dans un autre, et des cultures pures de *Chaetomium globosum*, *Coniella* sp., *Rhizoctonia solani* et *Trichoderma lignorum* se partagèrent les autres traitements.

En plus d'incorporer ces organismes au terreau, nous les avons mis en contact avec les différentes parties de la plante. *Rhizoctonia solani* ne tarda pas à couvrir les fraisiers d'une blanche toison de mycélium. Au bout d'une dizaine de jours, les trois fraisiers infectés étaient morts et les parties non désagrégées, complètement noircies. Les autres organismes n'ont pas semblé pouvoir endommager les fraisiers. *Botrytis* n'était pas inclus.

Sitôt cette expérience terminée dans la grande cage, nous l'avons reprise avec les mêmes organismes, mais en utilisant une quantité beaucoup plus faible d'inoculum, soit l'équivalent d'une cuillerée à thé, que nous avons disposé près du collet et en diminuant de moitié l'humidité pour empêcher qu'un excès de mycélium superficiel obscurcisse les résultats.

Cette fois, *Rhizoctonia* forma à la surface du terreau des filaments mycéliens épars, presque hyalins, ressemblant aux toiles d'araignée; des lésions noirâtres, profondes et sèches, semblables à celles observées en serre sur les fraisiers originaires de l'École d'Agriculture, se produisirent seulement sur les parties à fleur de sol.

Les racines dans les pots inoculés de *Fusarium* avaient bien certaines lésions, mais comme des racines saines se formaient à partir de ces lésions, nous ne pouvions guère les considérer comme dommageables. Les fraisiers témoins et ceux des autres traitements demeurèrent indemnes.

Parallèlement, les petites cages furent employées pour tester la pathogénicité de *Gloeosporium* sp., *Septoria aciculosa*, *Coniothyrium* sp., *Phoma* sp., *Sporocybe* sp., *Zythia fragariae* et *Botrytis* sp. du type *cinerea*. Chaque cagette contenait douse petits pots, dont trois devaient servir pour les témoins, trois pour les fraisiers inoculés sur le limbe des feuilles, trois pour ceux inoculés aux racines et tiges et les trois autres pour les fraisiers inoculés aux pétioles et stolons. Des divers organismes à l'essai, *Botrytis* seul put attaquer les fraisiers. Des lésions extensives portant des fructi-

TABLEAU 1.—APTITUDE DE DIVERS ORGANISMES À PRODUIRE LA GANGRÈNE SUR LE FRAISIER

Organismes	Lésions initiales sur			
	feuilles	coulants	tiges	racines
Témoin	−	−	−	−
Bactéries	−	−	−	−
Botrytis sp. du type cinerea	+	+	+	+
Chaetomium globosum	−	−	−	−
Coniella sp.	−	−	−	−
Coniothyrium sp.	−	−	−	−
Fusarium sp.	−	−	−	−
Gloeosporium sp.	−	−	−	−
Mucor sp.	−	−	−	−
Nématodes	−	−	−	−
Phoma sp.	−	−	−	−
Rhizoctonia sp. du type solani	+	+	+	+
Rhizopus nigricans	−	−	−	−
Septoria aciculosa	−	−	−	−
Sporocybe sp.	−	−	−	−
Trichoderma lignorum	−	−	−	−
Zythia fragariae	−	−	−	−

FIGURE 1. Fraisier sain. Témoin.

fications du pathogène se formèrent sur les parties aériennes, mais les racines demeurèrent intactes.

III

Botrytis et *Rhizoctonia* ont donc paru pouvoir causer des nécroses progressives du fraisier. Pour le vérifier, nous avons, dans des tests subséquents en serre, comparé leur action, ensemble ou séparément, à celle des autres champignons inclus dans la série d'essais ci-dessus rapportés.

La grande cage, contenant vingt-huit pots de terreau stérilisé, fut employée pour comparer l'action de *Botrytis* et de *Rhizoctonia* à celle des autres champignons en mélange. Des fraisiers sains de la variété Campbell furent utilisés. L'inoculum fut disposé près des tiges. Sept pots servirent de témoins. Les traitements, comprenant trois pots chacun, comportèrent, respectivement: *Rhizoctonia*, *Botrytis*, *Rhizoctonia* et *Botrytis*, autres champignons, *Rhizoctonia* et autres champignons, *Botrytis* et autres champignons, et, enfin, *Rhizoctonia* et *Botrytis* et autres champignons. *Rhizoctonia* et *Botrytis*, ensemble ou séparément, mélangés ou non aux autres champignons, montrèrent sensiblement la même agressivité en s'attaquant à la base des pétioles, qui finissaient par s'étendre sur le sol et mourir. Les racines demeurèrent indemnes. Les témoins et les fraisiers inoculés avec les autres champignons, à l'exclusion de *Botrytis* et de *Rhizoctonia*, ne furent pas infectés.

IV

Pour explorer davantage les possibilités d'interaction des divers organismes à l'essai dans le développement des gangrènes du fraisier, nous avons effectué, avec de jeunes fraisiers sains de la variété Campbell, dans des pots de 13 cm. remplis de sable stérilisé et disposés sur une table de la serre, ces quelques essais plus élaborés. Neuf pots servirent de témoins, neuf contenaient *Botrytis*, neuf, *Rhizoctonia*, et neuf autres, *Botrytis* et *Rhizoctonia*, tandis que les autres organismes à l'étude furent ensemencés dans les autres pots à raison de neuf pots par genre d'organisme. De ces neuf pots, trois reçurent en plus *Rhizoctonia* et trois autres, *Botrytis*, en sorte qu'il restait trois pots pour les divers organismes ensemencés séparément. Ces organismes étaient les suivants: bactéries, nématodes, *Phoma* sp., *Coniothyrium* sp., *Fusarium* sp., *Sporocybe* sp., *Mucor* sp., *Septoria aciculosa* et *Zythia fragariae*

L'inoculm, prélevé de cultures sur un mélange de blé et d'avoine, fut disposé au niveau des tiges. Le temps se maintint relativement frais et sec et nous ne pouvions guère contrôler les conditions dans la serre. Au bout de vingt-cinq jours, les témoins étaient intacts. Plusieurs fraisiers dans les pots ensemencés d'autres organismes s'infectèrent de *Botrytis*, dont les spores, transportées par les courants d'air, trouvèrent dans le mélange blé-avoine un milieu favorable à leur germination. Nous en avons déduit que la présence d'autres organismes n'avait pas entravé la croissance de *Botrytis*, mais l'avait au contraire favorisée, comme ce fut particulièrement le cas pour *Fusarium* et *Coniothyrium*.

Cinquante pour cent des plantes inoculées de *Botrytis* seul ou de *Rhizoctonia* seul étaient encore viables, tandis que vingt pour cent seulement ont pu survivre à l'infection par *Botrytis* et *Rhizoctonia* ensemencés ensemble. Des vingt-sept fraisiers inoculés de *Rhizoctonia* en mélange avec d'autres organismes, neuf étaient complètement détruits, neuf n'étaient pas viables, alors que les neuf autres présentaient seulement des symptômes de la pourriture du collet avec regénération des racines. D'une façon analogue, les deux tiers des fraisiers inoculés de *Botrytis* en présence d'autres organismes succombèrent par suite de l'infection des racines, tandis que l'autre tiers n'étaient atteints que de moisissure grise sur les parties aériennes.

V

A la lumière des résultats précédents, consignés dans le tableau 1, nous avons finalement tenté de reproduire la gangrène-botrytis et la gangrène-rhizoctone typiques, en serre, en utilisant la grande cage, du sable stérilisé, vingt pots de vingt-trois cm. avec soucoupes et des jeunes plants en parfaite condition de la variété Sierra.

Des cultures vigoureuses de *Botrytis* et de *Rhizoctonia* sur blé préalablement humecté et stérilisé servirent pour l'ensemencement. L'inoculum fut incorporé et bien mélangé au sable à raison d'une partie de blé inoculé pour deux parties de sable. Du blé stérilisé mais non inoculé fut mélangé dans les mêmes proportions au sable dans les pots témoins.

Sept pots contenant *Rhizoctonia* et sept ensemencés de *Botrytis* furent disposés séparément, et cinq autres pots servirent de témoins.

La température ne s'éloignait guère de 24° C. et l'humidité relative se tenait près du point de saturation. On n'ouvrait la porte de la cage que pour verser de l'eau distillé dans les soucoupes, au besoin.

Dès le cinquième jour, les plants inoculés de *Botrytis* ou de *Rhizoctonia* présentaient des symptômes et des signes de gangrène. En effet, *Botrytis* sporulait sur des lésions brunes à la base des pétioles et *Rhizoctonia* couvrait d'un feutrage dense de filaments blancs les pétioles visiblement affaiblis. Le dixième jour, plusieurs plants avaient sucoombé et plusieurs autres s'effondraient, en sorte que nous pouvions procéder à l'examen des racines.

Tous les fraisiers inoculés manifestaient, sur leurs divers organes, des symptômes et des signes de gangrène (figures 2 et 4), pendant que les cinq témoins étaient demeurés sains (figure 1). *Botrytis* a pu gangrener plus rapidement les racines que ne l'a fait *Rhizoctonia*. Les jeunes comme

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Explication des figures 2-5:

FIGURE 2. Fraisier gangrené par *Botrytis* sp. du type *cinerea*.

FIGURE 3. Fructifications de *Botrytis* sp. du type *cinerea* sur parties de racines atteintes de gangrène-botrytis (38×).

FIGURE 4. Fraisier gangrené par *Rhizoctonia* sp. du type *solani*.

FIGURE 5. Lésions gangréneuses et sclérotes sur parties de racines affectées de gangrène-rhizoctone (22×).

FIGURES 2-5.

FIGURE 6. Racines en partie gangrenées par *Rhizoctonia* sp. du type *solani*, dont on peut voir des sclérotes et filaments mycéliens (9×).

les plus vieilles lésions causées aux racines par *Rhizoctonia* étaient noirâtres, tandis que celles provoquées par *Botrytis* étaient brunâtres, avant de noircir. Des fructifications de *Botrytis* pouvaient s'observer sur toutes les parties attaquées par ce champignon, limbes, pétioles, tiges, racines (figure 3), stolons. D'un autre côté, on pouvait reconnaître le mycélium de *Rhizoctonia* sur les parties aériennes infectées par cet organisme, qui a pu former sur les racines quantité de sclérotes (figures 5 et 6).

DISCUSSION ET CONCLUSION

Botrytis sp. du type *cinerea* et *Rhizoctonia* sp. du type *solani* peuvent attaquer le fraisier en n'importe quel point, lui causer des maladies cataloguées suivant les parties affectées, ou gangrener toute la plante avec une rapidité foudroyante.

Botrytis et *Rhizoctonia* ne sont pas que de simples facteurs impliqués dans la pourriture des racines du fraisier. Nos travaux nous permettent de les considérer comme des agents directs de cette affection.

La pourriture des racines n'est pas toujours une manifestation de gangrène, mais elle nous a paru l'être le plus souvent. Berkeley (2) stipule qu'on ne doit pas considérer comme "pourritures des racines" des affections pouvant s'étendre à d'autres parties de la plante. Nous ne nous sommes donc pas attardé à vérifier si certaines espèces de *Fusarium*, *Coniothyrium*, etc. peuvent faire pourrir les racines. Nous n'avons pas non plus cherché à reproduire des maladies localisées sur les parties aériennes seulement, bien que nous ayons inclus dans nos essais des organismes tels que *Zythia fragariae*. Seules nous intéressaient les lésions pouvant affecter n'importe quelle partie de la plante et se généraliser rapidement.

Il n'est pas toujours facile de déterminer quel organisme est le principal responsable dans un champ de fraisiers gangrenés. Généralement, les jeunes lésions causées par *Botrytis* sont de couleur brun-cannelle et celles provoquées par *Rhizoctonia*, brun foncé à noirâtres. Toutefois, on a rarement affaire à la gangrène-rhizoctone ou à la gangrène-botrytis typiques. Le plus souvent, les deux pathogènes sont présents et sont escortés d'un nombre considérable d'autres organismes.

Lorsqu'on veut isoler les organismes concernés, ce sont les vrais responsables d'une lésion gangréneuse qui se manifestent le moins facilement. Certains organismes commensaux ont paru pouvoir devancer ou supplanter *Botrytis* et *Rhizoctonia* dans la majorité des cas, même lorsqu'il s'est agi de réisoler ces pathogènes à partir de lésions produites sous contrôle.

Il nous a semblé préférable, pour cette raison, de recourir à l'examen direct des tissus infectés, après les avoir disposés sur du sable humecté en atmosphère semi-confinée. Les fructifications de *Botrytis* ou le mycélium de *Rhizoctonia* ne tardaient généralement pas à se manifester dans ces conditions, non plus, d'ailleurs, que d'autres organismes d'abord emprisonnés dans les tissus. Cette méthode permettra peut-être de déceler d'autres agents de gangrène du fraisier. Pour notre part, nous avons trouvé que les deux principaux agents de ce fléau dans la province de Québec sont *Botrytis cinerea* et *Rhizoctonia solani*. Nous abons observé que d'autres organismes, telles certaines espèces de *Fusarium* et de *Coniothyrium*,

peuvent favoriser les gangrènes causées par *Botrytis* ou *Rhizoctonia*. Il se peut que d'autres lignées de ces organismes ou d'autres espèces se comportent différemment.

Il saute aux yeux que les conditions écologiques comptent énormément dans le développement des gangrènes du fraisier. Dans un champ d'observation et de multiplication que nous avons aménagé au printemps 1951, des variations considérables pouvaient être notées dès la première année d'une partie à l'autre de cette plantation d'une quarantaine de mètres carrés, très hétéromorphe et diversifiée. Les parcelles les mieux avantagées n'étaient que touchées par la maladie, alors que celles dont les plantes étaient exposées à la sécheresse (terrain bombé) ou à un excès d'humidité (dépression) étaient beaucoup plus affectées.

Au cours de ces travaux, il arrivait que des jeunes fraisiers se détérioraient, parfois à cause de lésions aux parties aériennes, mais le plus souvent, par suite de l'infection de la plaie produite par l'incision du stolon avec les ciseaux. Le mal se généralisait bientôt, et les fraisiers qu'on pouvait introduire dans un pot pour remplacer ceux qui s'étaient gâtés avaient le même sort au bout de quelque temps.

Il était généralement possible de reconnaître sur ces plantes des signes de moisissure grise ou des symptômes de ce qu'on a rapporté comme des maladies bien distinctes dues à *Rhizoctonia solani* (3, 8, 18). Nous pouvons considérer ces diverses affections comme autant de manifestations de ce que nous appelons les gangrènes du fraisier.

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THE RELATIONSHIP OF CLEAN FLEECE WEIGHT TO BODY WEIGHT IN RANGE SHEEP[1]

S. B. Slen[2], H. F. Peters[3] and P. I. Myhr[4]

Experimental Farms Service, Canada Department of Agriculture

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ABSTRACT

This study was conducted to determine whether the degree of relationship between clean fleece weight and body weight in range sheep was sufficiently great that body weight would be a useful index in selection of future breeding stock for increased wool production. Data were obtained during the period 1948-52 from five different breeds of sheep maintained by the Experimental Farms Service. Although highly significant coefficients of correlation were obtained for these two characteristics within breeds and years only a relatively small portion of the variability in clean fleece weight was explained by body weight. No significant differences were found in the degree of correlation between the various breeds analysed or between years studied. The average coefficients of correlation of these characteristics for shearling ewes, mature ewes, and shearling rams, obtained by combining the variances and covariances, were 0.40**, 0.27**, and 0.47**, respectively. Similarly, the average regressions of clean fleece weight on body weight were 0.028, 0.016, and 0.028 pounds, respectively.

**p=.01.

INTRODUCTION

At the three Experimental Stations where this study was conducted considerable emphasis has been placed on clean fleece weight in assessing the relative merit of yearling sheep as replacement breeding stock. Clean fleece weight is one of the simplest characteristics on which selection can be based for maximum improvement in wool production because it measures the combined effects of staple length, density of fibres on the skin, and fibre thickness and in addition eliminates the non-heritable variables present in a raw fleece. To increase the efficiency of selection on this basis the relationship of clean fleece weight to various fleece and body characteristics has been or is being determined; i.e. fibre thickness (4), staple formation, maximum mature clean fleece weight, and body weight. Spencer, Hardy, and Brandon (6), in an analysis of the factors influencing wool production, obtained a non-significant coefficient of correlation between clean fleece weight and body weight in shearling Rambouillet ewes. However, Pohle and Keller (3) obtained highly significant coefficients of 0.42, 0.34, 0.38, and 0.30 for Rambouillet, Tarhee, Columbia, and Corriedale ewes, respectively. Ali *et al.* (1) reported a correlation coefficient of 0.40 between these two factors for range Rambouillet rams. The data presented in this paper deal with a project undertaken to determine whether the degree and type of relationship between clean fleece weight and body weight were sufficiently great that body weight would be a useful trait in the selection of future breeding stock for increased wool production. These data will provide additional information that will be useful in developing selection indices including clean fleece weight as one of the traits rather than staple length or grease fleece weight.

[1] Contribution from the Division of Animal Husbandry, Experimental Farms Service, Canada Department of Agriculture, Ottawa.

[2] Wool Specialist, Experimental Station, Lethbridge, Alberta.

[3] Superintendent, Range Experiment Station, Manyberries, Alberta.

[4] Animal Husbandman, Experimental Station, Swift Current, Saskatchewan.

TABLE 1.—COEFFICIENTS OF CORRELATION AND REGRESSION BETWEEN CLEAN FLEECE WEIGHT AND BODY WEIGHT IN RANGE SHEEP

Station	Breed	1948		1949		1950		1951		1952		Av. r for breeds	b_{xy} for breeds
		No.	r	No.	r	No.	r	No.	r	No.	r		
SHEARLING EWES													
Lethbridge	N.Z. Corriedale	11	0.01	8	0.58	9	0.76**	14	0.49	10	0.13	0.38**	0.026
Lethbridge	Can. Corriedale	78	0.38**	44	0.52**	42	0.49**	37	0.16	52	0.33*	0.37**	0.026
Lethbridge	Rambouillet	75	0.57**	82	0.53**	73	0.60**	47	0.48**	81	0.25**	0.49**	0.028
Swift Current	Rambouillet	—	—	—	—	45	0.39**	45	0.46**	40	0.29	0.40**	0.032
Swift Current	Romeldale	—	—	—	—	23	0.18	23	0.48**	20	0.18	0.24	0.013
Manyberries	Romnelet	—	—	54	0.22	96	0.50**	53	0.28*	73	0.45**	0.33**	0.031
Av. r for years		164	0.45**	188	0.33**	288	0.47**	219	0.34**	276	0.33**	0.40**	0.028
MATURE EWES													
Lethbridge	Can. Corriedale	87	0.17	49	0.22	118	0.22*	107	0.48**	103	0.20*	0.24**	0.014
Lethbridge	Rambouillet	102	0.09	49	0.15	134	0.25**	121	0.22*	299	0.31**	0.24**	0.013
Swift Current	Rambouillet	—	—	—	—	20	0.24	41	0.52**	43	0.53**	0.47**	0.033
Swift Current	Romeldale	—	—	—	—	19	0.51*	24	0.49*	19	0.28	0.41**	0.020
Manyberries	Romnelet	—	—	47	0.33*	138	0.35**	177	0.26**	206	0.20**	0.27**	0.016
Av. r for years		189	0.13	145	0.20*	429	0.30**	470	0.34**	670	0.27**	0.27**	0.016
SHEARLING RAMS													
Lethbridge	N.Z. Corriedale	3	0.48	5	0.90**	4	−0.17	4	0.24	13	0.63*	0.57**	0.028
Lethbridge	Can. Corriedale	26	0.33	11	0.20	24	0.57**	15	0.37	27	0.48**	0.47**	0.025
Lethbridge	Rambouillet	25	0.52**	26	0.28	36	0.67**	22	0.64**	42	0.33**	0.47**	0.027
Swift Current	Rambouillet	—	—	—	—	35	0.67**	20	0.76**	23	0.37	0.64**	0.043
Swift Current	Romeldale	—	—	—	—	18	0.08	18	0.48*	18	0.68**	0.41**	0.028
Manyberries	Romnelet	—	—	—	—	38	0.28	23	0.54**	41	0.43**	0.40**	0.023
Av. r for years		54	0.44**	42	0.43**	155	0.44**	102	0.54**	164	0.46**	0.47**	0.028

*p = 0.05. **p = 0.01.

PROCEDURE

Clean fleece weights and body weights were obtained from 1,135 shearling ewes, 517 shearling rams, and 1,903 mature ewes ranging in age from two to seven years. Five different breeds were included in this study, namely, New Zealand Corriedale, Canadian Corriedale, Rambouillet, Romnelet, and Romeldale. The number of mature rams available was not sufficient to be included in this study. The New Zealand Corriedales, Canadian Corriedales, and part of the Rambouillets were maintained by the Experimental Station, Lethbridge, Alberta, under normal range conditions. Some winter feeding was done during severe weather and also during lambing until green grass became available. The Romnelets were ranged under similar conditions at the Range Experiment Station, Manyberries, Alberta. The remainder of the Rambouillets and the Romeldales were maintained at the Experimental Station, Swift Current, Saskatchewan, under range conditions during the summer months and under farm conditions during the winter months.

Composite wool samples weighing approximately 200 grams were obtained from each fleece at shearing time for clean fleece weight determinations. After the fleece was shorn from the sheep it was thrown on to a slatted grading table, flesh-side down, in a manner such that it was well spread out. The fleece then was skirted lightly and sampled. The procedure in sampling consisted of taking many small subsamples from the fleece in a definite pattern so that a representative sample was obtained. The belly wool was sampled in a similar manner and included with the fleece sample. These samples then were scoured and the percentage yield of clean wool was determined in accordance with standard laboratory procedure as outlined by Wilson (7). Fleeces from the shearling stock represented 12 to 14 months of wool growth, depending on date of birth, while those from the mature ewes represented 12 months' growth.

The body weights of the sheep included in this project were taken each year within two weeks after shearing.

The relationship of clean fleece weight to body weight was determined by means of correlation and regression analyses. The data were checked for linearity and the correlation and regression coefficients were tested for heterogeneity before combining year data to calculate average relationships.

RESULTS AND DISCUSSION

The individual coefficients of correlation and the average coefficients by breeds and years are shown in Table 1.

RESULTS AND DISCUSSION

It is evident from these data that although not all of the coefficients of correlation for each breed in each year were significant the average coefficients for breeds obtained by combining the year data, using the method of Snedecor (5), were highly significant. The Romeldale shearling ewes were an exception to this. On the basis of the average correlation coefficients for shearling and mature ewes and shearling rams, it was found that only 16 per cent, 6 per cent, and 22 per cent, respectively, of the variation in clean fleece weight could be explained by body weight. There-

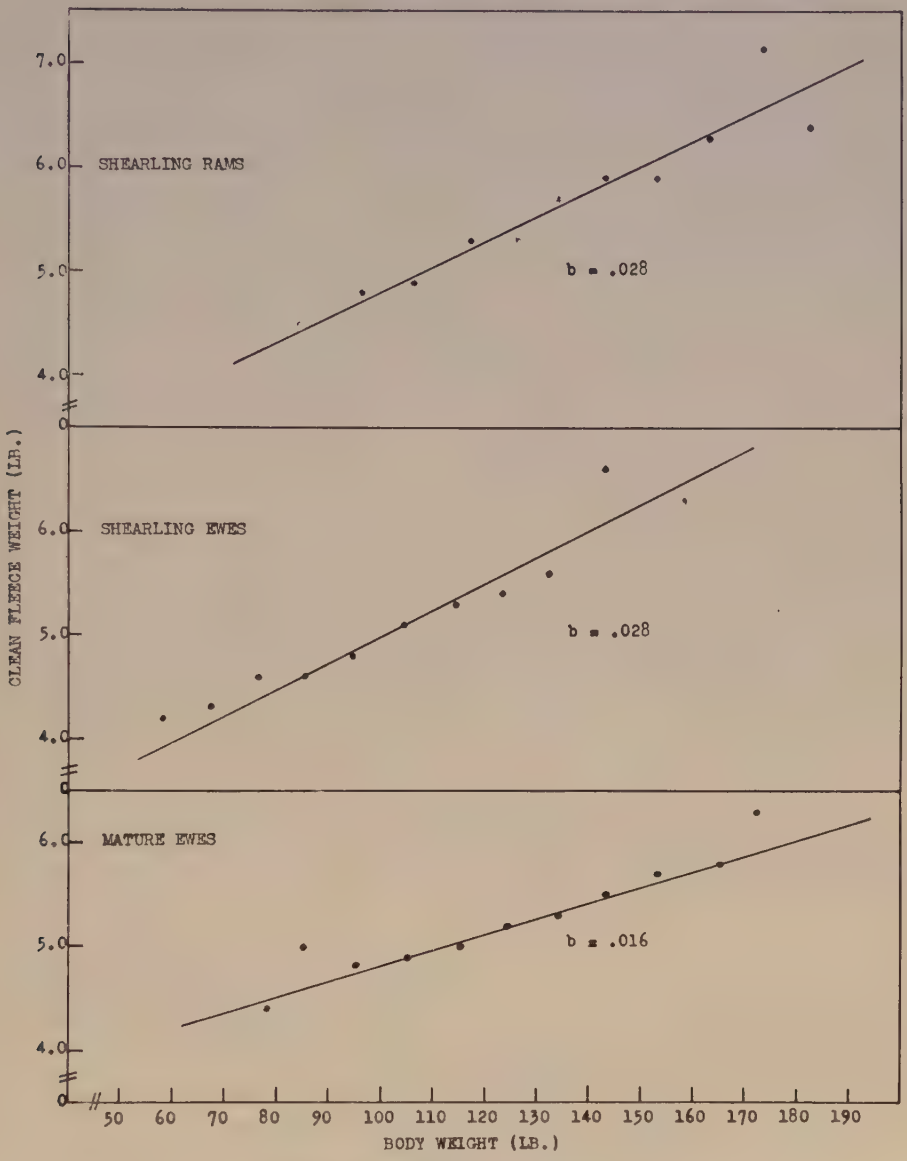

FIGURE 1. Relationship of clean fleece weight to body weight (1948-52).

fore, in developing a selection index that will place the maximum amount of emphasis on clean fleece weight other relationships to fleece and body characteristics should be determined. There were no significant differences between the coefficients due to Stations, years, or breeds. Significantly higher coefficients of correlation were obtained for shearling ewes and rams than for mature ewes. It may be that differences in the ages of the yearling stock at shearing time had an influence on the relationship since the older ones normally would be heavier and have grown more wool than the

younger ones. However, the effect of pregnancy, number of lambs born and raised, and age on body weight and wool production of the mature ewes may have been such that the relationship was reduced. These results are in general agreement with those of Ali (1) and Pohle and Keller (3) but considerably higher than the results obtained by Spencer *et al.* (6) from shearling Rambouillet ewes where the range in ages was similar to that of the present study.

The data on clean fleece weights were found to be linear as indicated in Figure 1. Several workers (2, 8) have reported that in the case of raw fleece weights the relationship was not completely linear and when a certain body weight was reached wool production began to decline. Evidently this was due to the fact that under certain range conditions the large ewes were unable to obtain sufficient extra feed to maintain their body functions and produce as much wool as a medium sized ewe. Under the range conditions on the Stations in western Canada this did not appear to be true for clean wool production. However, when these data were considered on the basis of clean wool production per unit of body weight it was found that the heaviest ewes were not necessarily the most efficient producers.

The coefficients of regression for clean fleece weight on body weight also are shown in Table 1. The coefficients were tested for heterogeneity and it was found that there were no significant differences between breeds. The average regressions of fleece weight on body weight were 0.028, 0.016, and 0.028 pounds for shearling ewes, mature ewes, and shearling rams, respectively.

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LEACHATES FROM DECOMPOSING LEAVES

II. INTERACTION WITH SOIL-FORMING MATERIALS[1]

L. E. Lutwick[2] and W. A. DeLong[3]

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ABSTRACT

The capacities of leachates from decomposing leaves of deciduous trees to attack calcareous and non-calcareous parent materials (taken from the C horizons of a brown forest and a podsol soil respectively), and soil from the B horizon of a podsol have been examined. The changes in the composition of extracts obtained in this way when brought into contact with other soil materials also have been studied. Attempts have been made to ascertain the chemical form or forms in which iron exists in the leachates and in the extracts obtained by the action of these leachates on soil and parent material.

Leachates from both beech and maple leaves extracted iron from both parent materials and calcium from the calcareous till, but lost the latter element to the podsol parent material.

The solution obtained by action of beech leachate on soil from the B horizon of a podsol was more acidic and had a greater capacity to extract iron from the parent materials than had the original beech leachate.

Most of the iron present in leachates from maple leaves was not removed from solution by passage over a cation and an anion exchange resin, but most of the iron added to such leachates as iron salts was retained by these resins. When iron salts were added to maple leachate a major part of the iron so added was not reactive with 2,2′-dipyridyl. Most of the iron extracted by maple leachate from the sandy parent material migrated toward the negative pole under electrodialysis.

The development of the podsol profile has been attributed to the action of acidic substances derived from decomposition of the organic materials in the A_{00} and A_0 layers (7). Attempts have been made to determine the mechanism of the process by laboratory studies employing colloidal humus extracted from soil (3, 4). Organic acids of low molecular weight, such as might be produced in the decomposition of organic matter, also have been used in such researches (5, 8).

The present investigation has sought to obtain information on the mechanism of the podsolization process through the use of solutions obtained by the leaching action of natural precipitation on decomposing leaves (1, 10). The capacity of such leachates to attack calcareous and non-calcareous parent materials and soil from the B horizon of a ground-water podsol has been examined. The changes in composition of extracts obtained in this way, when they were brought into contact with other soil materials, also have been studied. Attempts have been made to ascertain the chemical form or forms in which iron exists in the leachates and extracts. The present constitutes a progress report with special emphasis on the behaviour of iron.

EXPERIMENTAL MATERIALS

The parent materials used were taken from the C horizons of the Grenville (St. Bernard) and the Ste. Sophie soils, representatives of the brown forest and the podsol groups, respectively. The vegetative cover

[1] Contribution from the Faculty of Agriculture, McGill University, Macdonald College, Que., and the Dominion Experimental Farms Service. Macdonald College Journal Series No. 349.

[2] Agricultural Research Officer, Soil Chemistry Unit, Chemistry Division, Canada Department of Agriculture, Ottawa, Ontario.

[3] Associate Professor of Chemistry, Macdonald College.

at the sampling sites was forest, the most abundant species at the Grenville site being sugar maple (*Acer Saccharum*), that at the Ste. Sophie site American beech (*Fagus grandifolia* Ehrh.). The sites were situated in the Morgan Arboretum at Macdonald College, Que. They were located with the aid of a soil map prepared by P. Lajoie of the Canada Soil Survey Service (*unpublished*). The samples were taken at a depth of about 30 inches. The material obtained at the Grenville site was a calcareous gravelly loam till derived mainly from dolomitic rocks of the Beekmantown formation. The Ste. Sophie sample consisted mainly of fine sand which had been water-deposited over Champlain clay. More complete descriptions of these soils may be found in the report by Lajoie and Stobbe (9).

The ground-water podsol material, hereinafter designated B-soil, was collected under mixed beech-hemlock cover in the Morgan Arboretum, where this kind of profile occurs as the imperfectly drained member of the St. Amable complex (9). The sample was taken from a depth of 18 to 22 inches. In place, this material had the consistence and colour of orterde.

The samples collected were allowed to air-dry, after which representative portions were crushed and screened over a 1.0 mm. sieve. Only that portion passing this sieve was used in the experiments described below. The pH values after air-drying and sieving were 7.89, 5.15 and 4.97 for the Grenville, Ste. Sophie and B-soil materials, respectively.

The leachates employed were obtained as described previously (1, 10). Those used in the present study were derived from leaves of American beech (*Fagus grandifolia* Ehrh.) growing on Ste. Sophie soil, and from leaves of sugar maple (*Acer Saccharum* Marsh) growing on Grenville soil.

The leachates used in the extraction of the Grenville and Ste. Sophie soil-forming materials were collected through the growing season of 1949 from leaves of the 1948 crop which had been exposed to leaching continuously from the end of the 1948 leaf-fall period. Successive collections of leachates were combined to form a batch. Six batches of each kind of leachate were obtained and numbered 1 to 6 as collected. Prior to experimental use the batches of leachates were stored in large galvanized-iron cans coated with asphalt paint in a refrigerated room at about 6° C. The cans were covered and the room was lighted only when materials were being placed in or removed from it.

The leachates used in the experiments with the B-soil, and those employed in the investigation of the chemical forms of iron in leachates and extracts—with the exception of the electrodialysis experiment, for which Batch 1 maple leachate (1949 collection) was used—were collected in 1950 from leaves of the 1949 crop. These leaves had been exposed only from early spring 1950, and they were inoculated by spraying with soil suspensions obtained by shaking with water either A_0 material (Ste. Sophie) or A_1 soil (Grenville), taken from the sites where the leaves were collected. The suspension from the A_0 material was applied to the beech leaves, that from the A_1 to the maple leaves.

EXPERIMENTAL METHODS

In the extraction of the two parent materials a 5-gm. sample was placed in a 3-1 conical flask, 750 ml. of leachate added, and the stoppered

flask placed on a horizontally-reciprocating shaker operated at the rate of 30 strokes per minute. Samples of the supernatant solution were withdrawn daily from the continuously shaken mixture for analysis for iron content, shaking being continued until the latter attained a maximum value. This maximum generally was followed by a decline. The extraction time for leachates of different batches varied from 4 to 10 days. It was approximately the same for beech and maple leachates of the same batch, or collection period, and for both parent materials. The time required to reach maximum iron content increased from Batch 1 (collected April 18 to May 9) to Batch 5 (collected September 19 to September 30), then decreased for Batch 6 (collected October 5 to November 12). After the extraction time for a given batch of leachate had been established other samples were extracted for the same period to obtain the solutions which were analysed.

In the extraction of B-soil, also in the preparation of extracts from the two parent materials for reaction with B-soil, a uniform extraction time of 3 days was employed. In case of extracts reacting with soil materials, sample weights of 3 gm. each were shaken with 450 ml. of extract, the proportion of soil material to solution remaining as above.

Prior to analysis all extracts were centrifuged at 2400 r.p.m. for 30 minutes. Aliquot portions of the supernatant solutions so obtained then were evaporated to small volume and oxidized with a nitric-sulphuric-perchloric acid mixture; leachates were treated similarly in these respects. The oxidized solutions were analysed for iron or for iron, aluminum and calcium. Iron was determined either as the 2,2′-dipyridyl complex, after adding an acetate buffer at pH 4.6 and after reduction with hydroxylamine (6, 11) or in the ferric form along with aluminum using ferron (2). Calcium was estimated by permanganate titration of the oxalate (12). pH measurements were made with a Beckman model G pH meter using a glass-calomel electrode assembly. Electrodialysis was performed in a Mattison-type unit. The resins used in the ion-exchange experiments were Duolite C-3 (cation) and Duolite A-2 (anion). These resins were used (*a*), in the unadjusted H- and OH- forms and (*b*), as the mixed ammonium-hydrogen and acetate-hydroxyl forms produced by leaching with ammonium acetate-acetic acid buffers adjusted to a given pH until the effluent solution had the same pH as the influent.

RESULTS AND DISCUSSION

Extraction of Parent Materials

The results of the experiments to determine the extractive power of leachates when shaken with parent materials are summarized in Table 1.

Examination of the data shows that the pH of the extracts usually was higher than that of the leachates. Also, iron invariably was extracted from both parent materials, and calcium extracted from the Grenville but usually lost to the Ste. Sophie material. In addition, it is seen that the beech leachates invariably lost aluminium to both parent forming materials, whereas the maple leachates nearly always extracted this element from both. The changes in calcium content of the leachates are of the kind which would be expected from the nature of the materials extracted. The variations in

TABLE 1.—CHANGES IN pH AND IN AMOUNTS OF IRON, ALUMINIUM AND CALCIUM (IN MILLIMOLES PER LITRE) ON INTERACTION OF LEACHATES WITH PARENT MATERIALS

Parent materials		⟶ Ste. Sophie				Grenville			
Leachate	Batch No.	pH	Fe	Al	Ca	pH	Fe	Al	Ca
Beech	1	—	+0.020	−0.177	+0.004	—	+0.030	−0.408	+0.785
	2	−0.08	+0.036	−0.075	0	+0.55	+0.066	−0.174	+0.631
	3	+0.29	+0.024	−0.158	0	+1.03	+0.107	−0.433	+0.702
	4	−0.08	+0.042	−0.131	−0.042	+0.14	+0.077	−0.339	+0.697
	5	+0.26	+0.042	−0.062	−0.006	−0.62	+0.227	−0.173	+0.896
	6	+0.10	+0.012	−0.495	+0.021	+0.53	+0.167	−1.184	+0.378
Maple	1	—	+0.025	−0.003	−0.020	—	+0.122	−0.065	+0.203
	2	+0.23	+0.048	+0.074	−0.034	+1.23	+0.135	+0.340	+0.464
	3	−0.05	+0.036	+0.411	+0.074	+0.84	+0.124	+0.172	+0.377
	4	+1.37	+0.039	+0.049	−0.039	+0.80	+0.150	+0.086	+0.188
	5	+1.42	+0.030	+0.104	−0.019	+0.55	+0.105	+0.074	+0.160
	6	+0.77	+0.021	+0.217	−0.053	+0.97	+0.151	−0.284	+0.186

aluminium content seem to be related to the botanical origin of the leachate used. At present no explanation of the differential behaviour of the leachates in this respect can be advanced.

Reaction of Extracts with Soil Materials

The results of the experiments conducted with extracts are recorded in Table 2. In this table the changes in the content of the three elements determined are given in terms of percentages gained or lost by the extract (content in extract = 100 per cent).

TABLE 2.—CHANGES IN EXTRACTS ON CONTACT WITH A SECOND SOIL MATERIAL

	Difference in pH	Percentage changes		
		Fe	Al	Ca
Extracts from Ste. Sophie parent material reacting with B-soil:				
Beech extract	−0.66	+25	− 8	−29
Maple extract	−0.72	+37	−12	−18
Extracts from Grenville parent material reacting with B-soil:				
Beech extract	−0.44	−39	+30	−62
Maple extract	−0.54	− 8	0	−17
Extracts from B-soil reacting with Ste. Sophie parent material:				
Beech extract	−0.10	+650	+28	−67
Maple extract	−0.06	+81	+ 9	− 6
Extracts from B-soil reacting with Grenville parent material:				
Beech extract	+1.43	+2350	+14	+402
Maple extract	+0.57	+469	−12	+43

Examination of this table shows that the pH of the extracts decreased in all instances except when extracts from B-soil reacted with Grenville parent material, in which case a rise in pH would be anticipated. Where decreases in pH occurred they were accompanied by loss of calcium, but there seemed to be no consistent relationship between the decline in pH and the amount of calcium lost. Major decreases in pH occurred on reaction with B-soil. It is suggested that the leachates may have extracted acidic substances from this material, or, alternatively, that new acidic substances or acidic groups were produced in the interaction of the extract with the B-soil.

It is seen also that extracts from Grenville material lost iron to B-soil, whereas all other extracts gained in iron content, especially those from the B-soil. The increased capacity for iron uptake of beech leachate after contact with B-soil, and the large difference from maple leachate in this respect, are especially noteworthy. No adequate explanation of this behaviour, or of the apparently erratic and generally small changes in aluminium content of the extracts, can be advanced at present.

Forms of Iron Present in Leachates and in Extracts

It was postulated that the leachates and extracts under investigation might contain the following forms of iron; (*a*) ferrous or ferric ions, or both, (*b*), these ions in complexes retaining a positive charge or having acquired a negative charge, (*c*), in complexes or compounds having little or no effective charge. On the basis of this hypothesis it seemed desirable to investigate the possibility of separation of different forms of iron by means of ion exchange resins.

An ion-exchange procedure was applied to the investigation of the forms of iron present in maple leachates collected July 15 and August 2, 1950. Aliquots of 100 ml. each of leachate were passed successively through pairs of cation- and anion-exchange columns. Thus, one aliquot was passed through a pair of columns in which the cation-exchanger came first, a second aliquot through another pair in which the anion-exchanger preceded the cation-exchanger. The volumes of resin used in the columns were 15.5 and 14.0 ml. of the cationic and anionic forms, respectively. The cationic resin was used in the H-form, the anionic in the OH-form. The total iron contents of the leachates used were 0.116 and 0.136 mgm. per ml., respectively. The results obtained are reported in Table 3. One aliquot of the July 15th leachate and five successive aliquots of the August 2nd leachate were passed through each pair of exchange columns.

The most notable features of the data presented in this table seem to be; (*a*) the rather small proportion of the total iron retained; (*b*) the relatively uniform amounts of iron withdrawn from the leachates, and (*c*) the fact that the first resin passed removed the greater part of the iron lost from the leachate regardless of whether this was the cation or the anion resin. The last-mentioned characteristic suggests that adsorption, or precipitation, rather than ion-exchange is the principal cause of iron retention by these resins. The fact that about half the iron passed both resins suggests that a part at least of the leachate iron may be relatively freely mobile in the soil profile.

TABLE 3.—RETENTION OF IRON OF MAPLE LEACHATES BY ION-EXCHANGE RESINS

Leachate	Milligrams iron retained by individual resins				Per cent iron retained by resin pairs	
	Cation-anion		Anion-cation		Cation-anion	Anion-cation
Collected July 15—						
Aliquot 1	0.053	0.016	0.077	0.000	60	66
Collected August 2—						
Aliquot 1	0.047	0.007	0.044	0.017	40	45
2	0.034	0.021	0.037	0.017	40	40
3	0.015	0.026	0.050	0.012	30	45
4	0.050	—	0.058	0.010	—	50
5	0.046	0.020	0.072	0.028	48	73

The data obtained in this initial experiment with the ion exchange resins being somewhat disappointing, it was thought possible that more encouraging results might be secured with solutions containing larger amounts of iron, more of which might be in cationic form. Therefore a further experiment was carried out in which maple leachate enriched with iron by addition of either ferrous or ferric sulphate was used. The leachate employed was collected on July 15, 1950. It contained 0.116 mgm. total iron before enrichment, and 1.065, and 1.050 mgm. after addition of ferrous sulphate and ferric sulphate, respectively. (These latter concentrations of iron are of similar order of magnitude to those obtained by extraction of soil materials, for example, the total iron concentration of an extract used in the next experiment to be reported was 0.960 mgm. per 100 ml.). Passage of the iron-enriched solutions through the resin columns began approximately thirty minutes after the iron salts were added. Here, as before, the resins were in the hydrogen and hydroxyl forms, respectively. The initial flow rate through the columns was 3 ml. per minute, but, as these solutions continued to pass through the columns, this rate was considerably reduced regardless of which resin was in the first position. Accumulation of a dark-coloured material near the top of the anion column was observed when this was the first in line. Such accumulation could not be detected—because of the colour of the resin itself—when the cation column was in this position. The results obtained are given in Table 4, as percentages of the added iron retained by each column and passing into the final effluent. In making these calculations it was assumed that the behaviour on the exchange resins of the original iron of the leachate was unaffected by the addition of the iron salts. That is, the amounts of iron retained on passing the unmodified leachate over them (Table 3) have been subtracted from those retained when the enriched leachates were used and the differences calculated as percentages of the amounts of iron added as salts.

Inspection of Table 4 shows that the partition of the added iron was, in fact, different from that of the original leachate iron. The most notable difference is that but a small proportion of this iron escaped retention by

TABLE 4.—PARTITION OF ADDED IRON ON EXCHANGE RESINS

First column	Form of iron added	Percentage of added iron		
		Retained on cation column	Retained on anion column	In final effluent
Cation	$FeSO_4$	87	2	11
Cation	$Fe_2(SO_4)_3$	93	7	0
Anion	$FeSO_4$	13	80	7
Anion	$Fe_2(SO_4)_3$	8	88	4

TABLE 5.—PARTITION OF IRON OF EXTRACTS AND OF LEACHATE ON EXCHANGE RESINS

Influence solution	Initial pH	Total iron mgm./100 ml.	Percentage distribution of iron			pH of final effluent
			Retained on first (cation) column	Retained on second (anion) column	In final effluent	
Part A. pH of resins not adjusted						
Extract from Grenville by maple leachate of July 15, 1950	—	0.960	21	4	75	—
Part B. pH of resins adjusted						
Maple leachate of July 15, 1950	6.3	0.096	Nil	32	68	6.7
Extract from Grenville by this leachate	6.8	0.720	Nil	29	71	5.9
Extract from Ste. Sophie by this leachate	6.6	0.200	19	86	−5	5.6

both resins. However, it is once more observed that, regardless of their relative positions, the first resin encountered retained the major part of the iron added to the leachate.

In the next experiments an attempt was made to adjust the pH values of both cation and the anion resin to that of the leachate or extract passed over them. This was done by preparing ammonium acetate buffer solutions—from ammonia solution and acetic acid—having pH values essentially the same as those of the leachates or extracts to be investigated. These buffer solutions were passed through the resin columns until the pH of the effluent was the same as that of the influent buffer. After this preparation of the columns the leachate or extract to be studied was added. The pH of the effluent solution (leachate or extract) from the first column was not readjusted before it entered the second column. The results of these experiments are reported in Table 5, which also contains data obtained when the pH of the resins was not adjusted.

Comparison of Part A of Table 5 with Table 4—pH of resins not adjusted in either instance—shows that the iron extracted from Grenville parent material behaves quite differently from that of the iron of iron salts added to the same leachate. Thus, 75 per cent of the extracted iron passes both exchange columns whereas more than this proportion of the iron added as iron salts was retained by the resins. It may be noted that reversal of the positions of the cation and anion columns made no difference in the proportion of iron extracted from the Grenville material which passed both resins.

Table 5 shows also that adjustment of the pH of the resins made no considerable difference in the retention of iron extracted from the Grenville material.

In Part B of Table 5 it is seen that the behaviour of iron extracted from the Ste. Sophie parent material—by another portion of the same leachate as used on the Grenville material—was radically different from that of the iron extracted from the latter, by far the major part of the iron of the former extract being retained by the anion column. Interpretation of this difference in the behaviour of the extracts obtained from the two parent materials is rendered difficult by the observation that the Grenville extract remained slightly turbid after centrifugation, and that some of the suspended material passed both columns. The amount of iron associated with the suspended material in the final effluent is not known.

Comparison of the results obtained after addition of iron salts (Table 4) with those obtained with unmodified leachates (Table 3) and with iron-enriched extracts (Table 5), shows that addition of inorganic iron salts led to behaviour on ion-exchange columns distinctly different from that of leachates and of extracts in respect of retention of iron by the resins. It is possible that the differences shown by added as compared to extracted iron may be due, in part, to the more extended time of contact with the leachate in the case of the latter, namely three days as compared with one-half hour for the iron salts. It is apparent also, from the data of Table 5, that the kind of parent material reacting with maple leachate had a very marked effect on the mobility of the iron over ion-exchange resin surfaces. It is perhaps unnecessary to emphasize that the mobility of iron over such surfaces does not necessarily reflect the fate of leachate or of extract iron moving over the surfaces in soil profiles. Nevertheless, the variations in behaviour toward the exchange resins must represent real differences in the physico-chemical constitution of these iron-containing solutions, and the results obtained are suggestive of the desirability of further investigation of such solutions.

In general, the results of these experiments with ion-exchange resins suggest that clean-cut separations of cationic, anionic and neutral forms of iron are unlikely to be obtained, at least with the resins and the techniques here employed.

Partition of Iron by Electrodialysis

An extract obtained by shaking maple leachate of Batch 1 with Ste. Sophie parent material was subjected to electrodialysis. A 3-cell apparatus of the Mattson type fitted with parchment membranes was employed.

TABLE 6.—FRACTIONATION BY ELECTRODIALYSIS OF THE IRON IN A MAPLE LEACHATE EXTRACT FROM STE. SOPHIE PARENT MATERIAL

Fraction	Iron, mgm.	Per cent of total iron
Cathode cell solution	0.17	6.7
Cathode cell precipitate	1.48	58.5
Central cell solution	0.16	6.3
Central cell precipitate	0.50	19.8
Anode cell solution	0.13	5.1
Anode cell precipitate	0.09	3.6

The solutions in the anodic and cathodic cells were replaced with distilled water on the second and the fourth days after starting dialysis. The experiment was discontinued on the fifth day, the amperage having returned to the original value and gas evolution at the electrodes being no longer appreciable. The distribution of iron obtained is shown in Table 6. In securing this information the iron was determined by the dipyridyl method.

The data of Table 6 indicate that the major part of the iron in this extract is positively charged. However, the degree to which this form of iron may have been derived, during the prolonged period of dialysis, from the decomposition of complexes or compounds of iron is unknown. The precipitate in the central cell formed mainly at the membrane on the anodic side of this cell. This fact, together with the observation that a small amount of iron was able to migrate into the anode cell, indicated that a considerable proportion of the iron present was associated with anionic material.

Partition of Iron by Chemical Action

In these experiments, the capacity of iron present in or added to maple leachate to react directly with 2,2′-dipyridyl, or with this reagent after the addition of hydroxylamine hydrocholoride, was measured. It was thought that the results obtained might provide information on the occurrence in these solutions of ferrous and ferric iron and, indirectly, on the presence or absence of very stable complexes or compounds of iron in the original leachate and in the leachate after addition of inorganic salts of iron.

The maple leachate used in these experiments was collected during the latter part of the 1950 season, had been in cool storage in the dark for some timé, and was exposed to laboratory conditions of light and temperature for 5 days before use. Ferrous and ferric sulphates were added, separately, and each at two concentrations, to 25 ml. aliquots of the leachate. The time from addition of the iron salts to the addition of the reagents for estimation of iron was about 30 minutes in all instances. Aqueous solutions of the iron salts were prepared at the same time and analysed similarly. The leachate employed contain 0.039 mgm. of iron per 25 ml., none of which reacted with dipyridyl after the leachate had been exposed to labora-

TABLE 7.—RECOVERY OF IRON ADDED TO MAPLE LEACHATE

Treatment	Iron concn., mgm./25 ml.	Percentage recovery			
		Aqueous solution		Leachate solution	
		Ferrous	Ferric	Ferrous	Ferric
Without hydroxylamine	0.022	64	0.0	27	23
With hydroxylamine		100	100	41	32
Without hydroxylamine	0.087	84	5	48	23
With hydroxylamine		100	100	49	44

tory conditions for 5 days (7.7 per cent of its iron content was reactive to dipyridyl immediately after removal from cool storage). The data obtained are presented in Table 7.

Inspection of these results indicates, first, that added iron, whether ferrous or ferric, reacted with the leachate to form complexes or compounds which did not interact with 2,2′-dipyridyl to produce a coloured complex, the recoveries from the iron-enriched leachates in all instances being less than from the aqueous solutions. Further, it appears that the extent of this type of reaction was increased by increasing the concentration of iron in the leachate solution, and that ferrous iron was somewhat less reactive in this respect than ferric.

CONCLUSIONS

It has been shown that leachates produced from decomposing beech and maple leaves by natural precipitation are capable of extracting iron from both water-deposited sand and calcareous till taken from the C horizons of a podsol and a brown forest soil, respectively. The beech leachates lost aluminium to both these soil-forming materials whereas the maple leachates nearly always extracted this element. Both kinds of leachates extracted calcium from the till and usually lost it to the acidic sand. In general, the pH of the extracts was higher than that of the leachates.

The changes in pH and in content of the same three elements when leachate-extracts obtained from one soil material were allowed to react with a second have been determined. The most pronounced effects were noted when the extract was prepared by interaction of beech leachate with soil from the B horizon of a sandy ground-water podsol. This extract was more acidic than the original leachate and it possessed a greatly enhanced capacity for extraction of iron from C-horizon material.

Attempts have been made to determine the chemical forms of iron present in leachates, extracts, and leachates to which iron salts were added. It was found that the major part of the iron in a maple leachate was not retained by either the cation or the anion exchange resin used, and that the behaviour of the iron retained by these resins suggested that it was held by adsorption or precipitation rather than by ion-exchange. When ferrous or ferric sulphate was added to a maple leachate it was found that most of the iron so added was retained by the resins. Precipitation and adsorption

appeared to play major roles in this retention. Iron extracted from calcareous till by maple leachate was not retained by the resins, but that similarly extracted from C-horizon sand was retained almost wholly. Conclusions respecting the chemical forms of iron present could not be drawn from these experiments.

Electrodialysis indicated that most of the iron (about 65 per cent) in a maple extract from C-horizon sand was cationic. However, only a minor part (less than 10 per cent) of the iron present in a maple leachate reacted with 2,2′-dipyridyl. Further, both ferrous and ferric ions added to maple leachate as their sulphates were incompletely recoverable (23 to 49 per cent) by reaction with this reagent after one-half hour of contact. It was concluded that maple leachate is capable of converting ionic iron to stable complexes or compounds.

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Note added in press:

Since this paper was submitted for publication it has been learned that the 2,2′-dipyridyl reaction for the estimation of ferrous iron (hydroxylamine not added) is unreliable in presence of the organic matter of leaf extracts. The ferrous iron content of such solutions is over-estimated. A brief communication respecting observations in this connection is in preparation for publication.

— W. A. DeLong

THE EFFECT OF P^{32} RADIATION ON CROP GROWTH AND PHOSPHORUS UPTAKE

II. FIELD STUDIES[1]

E. PENNER[2]

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ABSTRACT

The results of field experiments with Thatcher wheat, designed to detect and measure deviations in plant growth and phosphorus absorption that may be ascribed to P^{32}, are presented. The assessment of radiation effects was based on those criteria normally utilized in testing fertilizer phosphorus availability by the tracer method.

Within the range of specific activities, 0-3600 microcruries P^{32} per gram P^{31}, both stimulatory and injurious effects may occur. Moreover, it appears that even at low specific activities (12μc P^{32} per gram P^{31}) the complete avoidance of deviations attributable to P^{32} are sometimes impossible.

These findings suggest no insurmountable obstacles to the use of tracer P^{32}; however, field experiments should be so designed that radiation effects can be detected when they occur.

P^{32} labelled phosphates have been used extensively in the past as a tool in phosphorus fertility and nutritional studies. This technique is permissible only if the growth processes of the test plants are not seriously interfered with as a result of P^{32} disintegration. Generally it has been assumed that this condition is met at low specific activities.

The results obtained by various research workers investigating the possibility of radiation effects are not in agreement. In a recent communication (5) some of these discrepancies have been briefly reviewed. In addition, some experimental evidence was presented which supported the view that the seriousness of radiation effects on cereal crops could depend on the condition of the experiment. Test plants grown in potted soils fertilized with radioactive ammonium dihydrogen phosphate in the granular form were only slightly affected in soil phosphorus absorption. Although these deviations occurred at levels of activity as low as 8 microcuries P^{32} per gram P^{31}, the magnitude of effect was considered too small to limit the use of P^{32} under greenhouse conditions.

Conclusions based on greenhouse studies however are not necessarily applicable under field conditions. Similar experiments were conducted in the Brown, Dark Brown and Black Soil Zones so as to provide representative climatic variations in Saskatchewan. The 1951 experiment in the Black Soil Zone was repeated in 1952 at somewhat different levels of activity. The results of two seasons of experimentation demonstrate the type and magnitude of radiation effects from tracer P^{32} that may occur. The evaluation of radiation effects are based on those criteria normally utilized in testing fertilizer phosphorus availability.

[1] Contribution from the Department of Soil Science, University of Saskatchewan. The material contained herein is part of a thesis submitted to the College of Graduate Studies in partial fulfilment for the degree of M.Sc.

[2] Graduate Student, Department of Soil Science, University of Saskatchewan; now with National Research Council, Ottawa.

EXPERIMENTAL METHODS

The locations of the experimental plots, together with their soil types* are given below:

(1) 1951	Kyle	Sceptre Heavy Clay	Brown glacial lacustrine soil
(2) 1952	Rosetown	Regina Heavy Clay	Dark brown glacial lacustrine soil
(3) 1951 and 1952	Melfort	Melfort Silty Clay Loam	Thick black glacial lacustrine soil

The test crop, Thatcher wheat, was fertilized at 24 lb. P_2O_5 as $NH_4H_2PO_4$, containing differential levels of P^{32} ranging from 0-3600 microcuries of P^{32} per gram of P^{31} in 1951 and from 0-720 in 1952†. The maximum activity used, 3600 microcuries P^{32} per gram P^{31}, is greater by a factor of 36 than that generally necessary in P^{32} tracer field experiments.

The trial plots were arranged in a randomized block design. Each treatment consisted of three 9-foot rows, spaced 6 inches apart. The length of rows was increased from 9 to 16 feet in 1952, of which 12 feet were harvested instead of 6 as in 1951. This was done in order to reduce sampling errors. In each case the middle row of the treatment was treated with radioactive phosphate; the two adjacent rows received the same rate of inactive phosphate. The number of replicates seeded depended on the number of harvests; six replicates were harvested at each sampling date.

The seeding operation was done with a specially made power seeder. The fertilizer attachment consisted of the belt arrangement from the V-Belt Kemp Seeder. The seeding mechanism, a portion of the Columbia Seeder, was set to meter Thatcher wheat at approximately $1\frac{1}{4}$ bushels per acre. Both the fertilizer and grain were sown at the same depth through a common shoe. The machine was propelled by a common garden tractor.

Edge effects were avoided by placing adjacent blocks directly side by side, while outside blocks were protected with additional rows of the same wheat. Although weeds were practically non-existent, plots were treated with commercial 2,4-D weed spray at recommended rates.

The above-ground material from each active row constituted one sampling unit. These materials were transported and oven-dried at 100° C. in brown paper bags of convenient size. Plant material harvested before maturity was ground to approximately 1 mm. in size; however, at maturity, to establish grain yields, the samples were first threshed with a cyclone thresher and cleaned with a fanning mill. The grain and straw were then separately ground for analysis.

The methods of radioactive fertilizer preparation, and of chemical and radio-chemical analyses of plant material were the same as those referred to in a previous publication (5) with one exception. To reduce counting time in the latter stages of growth a more efficient counting procedure than the briquet method (4) is desirable. For these harvests the method of counting outlined by Kristjanson *et al.* (2) was found satisfactory.

* A full description of these soils may be found in Soil Survey Report No. 12, Department of Soil Science, University of Saskatchewan.

† All specific activities refer to the activity at the beginning of the experiment.

EXPERIMENTAL RESULTS

1951 Results

Tables 1, 3 and 5 give the results of the three harvests at the Kyle location after 51, 75 and 90 days of growth; Tables 2, 4 and 6 give the corresponding data for Melfort after 45, 75 and 88 days of growth.

A decreasing trend in plant weight with increasing levels of activity may be noted for the first harvest at both locations (Tables 1 and 2); however, statistical treatment failed to show any significant differences at the 5 per cent point. Although adequate rainfall occurred at both locations it is fairly evident from the percentage fertilizer phosphorus used that the phosphorus-supplying power of these two soils was very dissimilar. Approximately twice the amount of phosphorus was recovered from the fertilizer in the Melfort experiment as compared to Kyle. In spite of this no statistically significant radiation effects could be detected at Melfort

TABLE 1.—THE EFFECT OF DIFFERENTIAL P^{32} LEVELS ON PLANT GROWTH AND PHOSPHORUS ABSORPTION—1951
Location: Kyle; first sampling
Days of growth, 51; length of row, 6′

Microcuries P^{32}/gr. P^{31}	Plant weight (grams)	Total P. (mgm.)	Soil P. (mgm.)	Fert. P. (mgm.)	Per cent Fert. P. recovery	Ratio $\frac{\text{Soil P.}}{\text{Fert. P.}}$
0	50.5	164	—	—	—	—
12	50.9	178	103	75	22.8	1.41
120	48.0	158	72	87	26.2	0.93
1200	47.3	149	58	91	27.8	0.69
3600	43.3	158	93	64	19.6	1.52
L.S.D. (P = 0.05)	N.S.	N.S.	32	N.S.	—	0.43

TABLE 2.—THE EFFECT OF DIFFERENTIAL P^{32} LEVELS ON PLANT GROWTH AND PHOSPHORUS ABSORPTION—1951
Location: Melfort; first sampling
Days of growth, 45; length of row, 6′

Microcuries P^{32}/gr. P^{31}	Plant weight (grams)	Total P. (mgm.)	Soil P. (mgm.)	Fert. P. (mgm.)	Per cent Fert. P. recovery	Ratio $\frac{\text{Soil P.}}{\text{Fert. P.}}$
0	64.8	270	—	—	—	—
12	61.4	270	111	158	48.5	0.68
120	59.4	263	115	148	45.2	0.75
1200	58.5	259	107	153	46.6	0.69
3600	54.3	239	108	131	40.0	0.81
L.S.D. (P = 0.05)	N.S.	N.S.	N.S.	N.S.	—	N.S.

on the basis of the criteria used, while at Kyle both soil phosphorus absorption and soil phosphorus/fertilizer phosphorus ratios show considerable P^{32} interference. Soil phosphorus absorption at Kyle decreased nearly 50 per cent at 1200 microcuries P^{32} per gram P^{31} compared to the 12 microcurie level, while the 3600 microcurie level was very similar to the 12 microcurie level. These results support the original findings of Russell *et al.* (7) that soil phosphorus/fertilizer phosphorus ratios may sometimes be altered in the absence of any marked alterations in plant weight.

Tables 3 and 4 give the results for Kyle and Melfort respectively at the second harvest. The results are at variance with those at the first harvest. The decrease at Melfort in both plant weight and total phosphorus for the active treatments, compared to the control, varied from the results at Kyle.

TABLE 3.—THE EFFECT OF DIFFERENTIAL P^{32} LEVELS ON PLANT GROWTH AND PHOSPHORUS ABSORPTION—1951
Location: Kyle; second sampling
Days of growth, 75; length of row, 6′

Microcuries P^{32}/gr. P^{31}	Plant weight (grams)	Total P. (mgm.)	Soil P. (mgm.)	Fert. P. (mgm.)	Per cent Fert. P. recovery	Ratio Soil P. / Fert. P.
0	238	392	—	—	—	—
12	235	373	253	120	36.6	2.35
120	254	361	225	136	41.4	1.66
1200	237	327	236	91	28.4	2.75
3600	197	305	190	115	35.1	1.76
L.S.D. (P = 0.05)	N.S.	N.S.	N.S.	N.S.	—	N.S.

TABLE 4.—THE EFFECT OF DIFFERENTIAL P^{32} LEVELS ON PLANT GROWTH AND PHOSPHORUS ABSORPTION—1951
Location: Melfort; second sampling
Days of growth, 70; length of row, 6′

Microcuries P^{32}/gr. P^{31}	Plant weight (grams)	Total P. (mgm.)	Soil P. (mgm.)	Fert. P. (mgm.)	Per cent Fert. P. recovery	Ratio Soil P. / Fert. P.
0	238	383	—	—	—	—
12	205	321	150	172	52.3	0.89
120	219	337	167	171	52.0	1.05
1200	202	355	182	173	52.7	1.09
3600	206	331	174	157	47.9	1.12
L.S.D. (P = 0.05)	25	37	N.S.	N.S.	—	N.S.

TABLE 5.—THE EFFECT OF DIFFERENTIAL P^{32} LEVELS ON PLANT GROWTH AND PHOSPHORUS ABSORPTION—1951

Location: Kyle; third sampling

Days of growth, 90; length of row, 6′

Microcuries P^{32}/gr. P^{31}	Plant weight (grams)	Total P. (mgm.)	Soil P. (mgm.)	Fert. P. (mgm.)	Per cent Fert. P. recovery	Ratio Soil P. / Fert. P.
0	280	327	—	—	—	—
12	305	442	354	88	26.8	4.6
120	328	521	400	121	36.8	3.4
1200	336	510	374	136	41.5	2.8
3600	211	336	231	106	32.3	2.2
L.S.D. (P = 0.05)	75	94	99	22	—	1.4

The third harvest was taken in the early milk stage after approximately three months of growth. The results are given in Tables 5 and 6 for Kyle and Melfort, respectively. Comparing the active rows to the control there is evidence of two opposing effects, stimulation in growth at lower levels of activity, and injury at the higher levels. Decrease in growth as a result of the presence of radioactive phosphorus seems to be fairly well understood; however, the cause of stimulation is not altogether clear.

Histological examinations of barley plants grown in nutrient solution containing P^{32} by Mackie *et al.* (3) showed cell division may decrease or cease in stem and root meristems as a result of tracer P^{32}. The existence of localized concentrations of phosphorus in the meristems of plant tissue is now well known and it is this phenomena that is believed to aggravate radiation injury.

Russell *et al.* (7) have attributed increases in shoot weight to reduced downward translocation as a result of severe root radiation injury. Bould *et al.* (1) have also observed stimulatory effects. Mackie *et al.* (3) have noted increases in cell size. No doubt this problem should be pursued in greater detail.

From a comparison of Tables 5 and 6 it may be noted that although the plant weight at 3600 microcuries decreased below the control, the total phosphorus content was not so affected. The stimulatory effects on soil and fertilizer phosphorus also decrease at the 3600-microcurie level. Although the interference attributed to P^{32} was generally similar in nature at both Kyle and Melfort at the final harvest, the deviations were considerably greater at Kyle. No statistical separations could be made at the Melfort location at the 5 per cent point (Table 6).

An increase of adventitious roots (not statistically significant) in the radioactive fertilizer zone, has been observed by Russell *et al.* (7) and as a consequence the soil phosphorus/fertilizer phosphorus ratio was altered. While no observations were made on the root systems in these experiments

TABLE 6.—THE EFFECT OF DIFFERENTIAL P^{32} LEVELS ON PLANT GROWTH AND PHOSPHORUS ABSORPTION—1951
Location: Melfort; third sampling
Days of growth, 88; length of row 6′

Microcuries P^{32}/gr. P^{31}	Plant weight (grams)	Total P. (mgm.)	Soil P. (mgm.)	Fert. P. (mgm.)	Per cent Fert. P. recovery	Ratio Soil P. / Fert. P.
0	267	331	—	—	—	—
12	280	342	210	132	40.2	1.6
120	269	406	252	154	46.9	1.7
1200	283	423	256	167	50.9	1.6
3600	255	379	238	141	43.1	1.7
L.S.D. (P = 0.05)	N.S.	N.S.	N.S.	N.S.	—	N.S.

the soil phosphorus/fertilizer phosphorus ratios decreased with increasing levels of activity at the final harvest at the Kyle location indicating that a similar process may have been operative at this stage of growth.

1952 Results

The 1951 field experiments were repeated in 1952 with some modifications. The length of sampling row was increased from 6 to 12 feet, and the number of levels of specific activity was also increased. These were spaced over the lower range used in 1951, and were 0, 12, 60, 120, 240 and 720 microcuries P^{32} per gram P^{31}. The number of harvests was reduced to two, the first harvest being taken in the actively growing stage, and the final one at maturity to obtain information on the effect of tracer on grain yields. The plots were located at Melfort, near the 1951 site, and at Rosetown.

TABLE 7.—THE EFFECT OF DIFFERENTIAL P^{32} LEVELS ON PLANT GROWTH AND PHOSPHORUS ABSORPTION—1952
Location: Rosetown; second sampling
Mature harvest; length of row, 12′

Microcuries P^{32}/gr. P^{31}	Yield bu./acre	Plant weight (grams)	Total P. (mgm.)	Soil P. (mgm.)	Fert. P. (mgm.)	Per cent Fert. P. recovery	Ratio Soil P. / Fert. P.
0	35.5	399	663	—	—	—	—
12	38.5	440	709	523	187	28.5	2.82
60	38.8	438	719	541	178	27.2	3.04
120	39.5	438	733	584	149	22.7	4.01
240	35.4	411	681	513	168	25.6	3.05
720	40.8	447	765	593	172	26.2	3.48
L.S.D. (P = 0.05)	N.S.	N.S.	N.S.	N.S.	21	—	0.67

The results of the first harvest at Rosetown and Melfort, and of the mature harvest at Melfort showed no effect from tracer P^{32} and for this reason the data have been omitted. At the final harvest at Rosetown (Table 7) a decrease occurred in the amount of phosphorus derived from the fertilizer for an intermediate P^{32} level. There is also some indication of P^{32} interference with the soil phosphorus/fertilizer phosphorus ratio which rises to a maximum at 120 microcuries. This level has a statistically significant higher ratio than all other treatments with the exception of the highest level, 720 microcuries P^{32} per gram P^{31}.

DISCUSSION AND CONCLUSIONS

The experiments reported are necessarily of a preliminary nature designed to gain information on variations attributable to P^{32}. Within the range of specific activities studied under field conditions it appears that both injurious and stimulatory effects may occur to alter the amount of plant growth, and in some instances alteration in soil phosphorus/fertilizer phosphorus ratios have occurred. One possibility is that the effects are related to the variable environmental conditions. Under greenhouse conditions plants fertilized with granular phosphorus fertilizer have shown little sensitivity to P^{32}; however, the environmental conditions were relatively uniform throughout the growing period (5). Under field conditions large fluctuations in temperature and rates of growth occur, therefore, more serious radiation effects might then be expected.

Some evidence on the effect of environment was obtained in a series of experiments (6) not reported here. Wheat seedlings were grown in sand culture at two different rates under controlled conditions, in a constant temperature cabinet. The only source of phosphate other than that contained in the seed was supplied as ammonium dihydrogen phosphate at differential P^{32} levels. Exodiffusion of seed phosphorus occurred from the roots of the most rapidly growing seedlings at a specific activity as low as 12 microcuries P^{32} per gram P^{31}.

A comparison of the field data from two seasons indicates that observations from any one set of experiments do not provide conclusive evidence for the accurate assessment of radiation effects. Of the ten separate harvests reported here, four show significant differences attributable to P^{32} in at least two of the criteria studied, but only in two harvests (first and third harvests at Kyle 1951), are the deviations of sufficient magnitude to cause any concern. Because of these results, it is not possible to set a range of specific activities where the absence of radiation effects can be guaranteed. It would appear advisable to repeat experiments designed to measure soil and fertilizer phosphorus absorption under field conditions, and preferably at more than one level of activity before sound conclusions may be drawn. This practice would afford some means of detecting whether radiation effects, such as injury or stimulation, were operative under the particular conditions of the experiment. Tracer P^{32} field experiments are subject to those limitations clearly shown in the results of the experiments presented, namely that the existence or extent of

radiation effects cannot be forecast even at low tracer levels. Provided the existence of these limitations is realized and adequate precautionary measures are practised the tracer method still provides an invaluable tool in fertilizer and nutritional studies.

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NOTE:

It has been pointed out by the author that, in Part I of this series ("Greenhouse Studies"), published in Volume 34, No. 1, January-February, 1954, while all the data were statistically analysed, he neglected to state that the L.S.D. (in all cases) was based on a probability (P) = 0.05.

NOTE ON THE MANAGEMENT OF RED CLOVER FOR SEED PRODUCTION[1]

Red clover is generally considered to be a biennial or short-lived perennial. It does not, however, behave in the manner of most biennials with rosette formation only in the year of seeding and flower formation and seed maturation in the second year. Rather, only a proportion of the plants may flower and set seed in the year of seeding.

Bird (1) has distinguished five growth types in the double-cut red clover commonly grown in Eastern Canada. The five types are shown in Figures 1 to 5, while Figure 6 shows a group of various types in the field. The five types may be described as follows with reference to the growth in the year of establishment:

Type O—produces rosette only, no flower formation (Figure 1).

Type I—produces strong rosette with one or a very few flower stems, prostrate (Figure 2).

Type II—produces fairly prominent rosette with a ring of flower stems, generally prostrate (Figure 3).

Type III—produces indistinct rosette with many flower stems, generally upright (Figure 4).

Type IV—produces no rosette, many sparsely leaved upright flower stems (Figure 5).

In the year of seeding it may therefore be possible to produce seed on Type IV and lesser amounts on II and III. However, the normal practice in Eastern Canada is to seed red clover with a companion crop, e.g. oats, with the latter harvested as grain. Thus very little blooming occurs in the year of seeding. In the following year an early forage cut is taken and the second growth allowed to produce seed. Hence the harvesting of seed in the year of seeding is a departure from this management practice. The study reported herein was made to investigate any changes that this practice might bring about in the constitution of a red clover variety. As previously stated, Bird's (1) work indicated that not all types would likely produce seed in the year of seeding; thus seed harvested under such conditions might well have proportions of the various growth types different from the proportions present in the parental stock.

Actually in the fall of 1952 a fortuitous harvest of seed in the year of seeding made by a western farmer provided the first real opportunity to study the effect of this management practice when used on a farm scale. This seed—designated herein as "seed lot X"—came from a field seeded with Lasalle red clover. The foundation stock of this variety is composed of equal quantities of Ottawa Red and Dollard red clovers. The latter variety is constituted so that it contains approximately 75 per cent of Types II and III and the remaining 25 per cent of O, I and IV. The Ottawa red variety is so similar to Dollard in field performance that its composition has been assumed as similar.

[1] Contribution from Faculty of Agriculture, McGill University, Macdonald College, Que. Journal Series No. 342.

PLATE I. Growth types of red clover.

In the spring of 1953 a space-planted nursery of seed lot X progeny was established in the experimental area of the Agronomy Department, Macdonald College. Late in August of 1953 all living plants (212 out of the original 230) were scored as to growth type according to Bird's classification. At the same time the plants in the regular red clover breeding nursery at Macdonald College, which is used to produce Dollard, were similarly scored by the same person. The proportions of these various growth types in the two nurseries are given in Table 1.

TABLE 1.—PERCENTAGES OF PLANT TYPES IN SEED LOT X AND DOLLARD RED CLOVER

Type	Seed lot X	Dollard
O	2	9
I	2	7
II	7	24
III	48	51
IV	41	9
Number of plants classified	212	792

It is apparent that a very marked change took place in the relative proportions of the various growth types. Seed lot X had a much higher percentage of type IV than is found in Dollard. In fact the percentages found in the lot of Dollard plants scored was exactly as expected. As previously mentioned, the two varieties used to constitute Lasalle are similar in performance and it is believed that they would have similar percentages of the various growth types. Also the variety Lasalle is expected to maintain approximately the same percentages. The percentages found in seed lot X differ so markedly from expected that it would not likely be accepted as representing the variety Lasalle. The chi-square test applied to these data—using those for Dollard as the expected percentages—gives a chi-square value of 134.99 with a probability of $p < .001$. This suggests that the deviation from expected is so great that it is not likely due to chance variation and hence it seems reasonable to attribute it to the practice of taking seed in the year of seeding. Certainly the conditions under which the seed was produced—whether due to climate, management or a combination of them—very definitely altered the stock from the expected percentages. This change might be undesirable and may well result in the variety being rejected by the seed consumers, i.e. those who grow the plant for forage in Eastern Canada.

Another change which it is anticipated might result from this management practice has to do with the stand remaining to produce seed in the following year. Several years' observations of the breeding block at Macdonald College indicate that, usually, plants which produce flowers and mature seed in the year of seeding do not survive the first winter. Thus

one may expect not only the seed harvested in the year of seeding to be atypical, but the seed from the over-wintered stand, harvested in the following year might also be atypical, due to the reduced proportions of the very early types and the increased proportion of the late types. This is of course an assumption and must be investigated.

These are preliminary data and apply to one lot tested in one season and, in addition, that lot represents only one area used for seed production. It would not be wise to generalize on other seed-producing areas. The need for caution in formulating a management policy for red clover is, the authors believe, amply demonstrated. The question, however, must be studied more extensively before the effect of this management practice can be assessed. Plans are now being made to carry on further investigations.

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— H. A. STEPPLER,
Associate Professor of Agronomy,
Macdonald College, Que.

— L. C. RAYMOND,
Professor of Agronomy,
Macdonald College, Que.

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